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N O T E

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2. Mathematical formulae in the original text employ three alphabets -- Roman, Greek, and Cyrillic. Cyrillic letters transliterated into Roman are underlined to avoid confusion.

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F R O M

M A C H I N E B U I L D I N G

A N E N C Y C L O P E D I C H A N D B O O K

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Chapter II

CUTTING PRACTICE FOR THE MECHANICAL PROCESSING OF MACHINE PARTS

Cutting Practice with High-Speed Tool Steel Cutters and Hard-Alloy-Tipped Cutters

Cutter wear. With relation to the material of the cutting part and the operating conditions, cutters sustain diverse wear. The permissible ultimate magnitudes of wear δ along the back face of high-speed steel cutters are given in Table 1, and for hard-alloy-tipped cutters -- in Table 2.

The magnitudes of cutting tool bit wear cited in these Tables are in conformance with conditions of efficiency and requisite technology in the machining of ferrous metals.

A machine operation with a wear in the cutting tool bit in excess of the tabular values results in quality deterioration, in a sharp reduction of the number of possible regrindings, and in the breaking of the tool.

Tool angles. The geometric parameters of the cutting parts of tools are to be selected as per GOST 2320 - 43 and as per authorized data for high-speed grinding, i.e.

$$\gamma = -5 \div -10^{\circ};\ \lambda = 5 \div 15,\ \text{and}\ r = 0.5 \div 1\ mm.$$

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Depth of cut. In rough-turning the depth of cut t is determined by the surplus stock. If the power of the drive and the rigidity of the entire unit are inadequate to remove the entire surplus stock in one pass, it is removed in two or more passes.

In precision work it is rational to remove the surplus stock in two or several passes. The depth of cut per each pass is established by practical considerations.

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Table 1

Wear in high-speed steel cutters

Types of cutter bits (1)	Operating conditions (2)	Permissible wear δ in millimeters (3)	Appearance of wear (4)	Indications pointing to blunting of bits (5)
Steel, cast steel, malleable cast iron				
Lathe (threading, undercutting and boring)	With cooling	1.5 - 2.0		The appearance of a bright or yellow band on the cutting surface
	Without cooling	0.3 - 0.5		
Planer (threading and undercutting)	Without cooling	1.5 - 2.0		
Slotter (threading)		0.3 - 0.5		

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Table 1 (continued)

(1)	(2)	(3)	(4)	(5)
Lathe (recessing and cut-off	With cooling	0.8 - 1.0		Sharp deterioration in the finish of machined surface
	Without cooling	0.3 - 0.5		
Planer (recessing and cut-off)	Without cooling	0.8 - 1.0		
Slotter (recessing and cut-off)				Machined surface shows ripples
Lathe (roundnose) and planer (broad-nose)	Without cooling	——		The appearance of dents on cutting edge and deterioration in finish of machined surface

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Table 1 (continued)

(1)	(2)	(3)	(4)	(5)
Gray Iron				
Lathe (threading)	Rough turning	3.0 - 4.0		Appearance of black scales on cutting surface and sharp deterioration in finish of machined surface.
	Semi-finished turning	1.5 - 2.0		Diameter of machined part increases by 0.1 millimeter
Planer (threading)	Longitudinal planing	3.0 - 4.0		Appearance of black scales on cutting surface and sharp deterioration in finish of machined surface
	Transverse planing	1.5 - 2.0		

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Table 1 (continued)

(1)	(2)	(3)	(4)	(5)
Slotter (threading)	Slotting work	0.8 - 1.0		Appearance of black scales on cutting surface and sharp deterioration in finish of machined surface.
Lathe (threading)	Lathe work	1.5 - 2.0		
Planer (undercutting)	Planing work			
Lathe (recessing and cut-off)	Lathe work	1.5 - 2.0		Sharp deterioration in finish of machined surface.
Planer (recessing and cut-off)	Planing work			
Slotter (recessing and cut-off)	Slotting work			Machined surface shows ripples.

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Table 1 (continued)

(1)	(2)	(3)	(4)	(5)
Lathe (roundnose) and planer (broad-nose)	Finish-turning and finish-planing	——		Appearance of dents on cutting edge and deterioration in finish of machined surface.

Note. When machining through skin (surface scales or sand bubbles), with depth of cut up to 3 millimeters, the permissible wear on cutter bits may exceed the above tabular values 1.5 times.

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Table 2

Wear in hard-alloy-tipped cutter bits

Types of cutter bits and grades of hard alloy (1)	Operating conditions (2)	Permissible wear δ in millimeters (3)	Appearance of wear (4)	Indications pointing to blunting of bits (5)
Steel, non-ferrous metals and light alloys, steel castings				
Turning, reinforced with hard titanium-cobalt alloy (Grades T5K10, T5K6, T21K8 and others)	$s \geqslant 0.3$	1.5 - 2.0		Appearance on the cutting surface of black or yellow band, and on the machined surface -- adhering black shavings
	$s \leqslant 0.3$	0.8 - 1.0		Appearance of white protruding stripes and small black shavings on machined surface
Turning, reinforced with hard alloy (Grade VK 8)	$s \geqslant 0.3$	0.4 - 0.6		Appearance of a yellow bright stripe on cutting surface. Local disintegration of cutting edge (small chipping).
	$s \leqslant 0.3$	0.5 - 0.7		

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Table 2 (continued)

(1)	(2)	(3)	(4)	(5)
		Cast Iron		
Turning, reinforced with hard tungsten-cobalt alloy (Grades VK 6 and VK 8)	$s \geqslant 0.3$	0.8 - 1.0		Chipping of cutting edge and the appearance (during high feeds) of yellow bright stripe on cutting surface.
	$s \leqslant 0.3$	1.4 - 1.7		Sharp increase in roughness of machined surface
Planing, reinforced with hard alloy (VK 8)	$s \geqslant 0.4$	1.0 - 1.2		Appearance of yellow stripe on cutting surface
	$s \leqslant 0.4$	1.5 - 2.0		Sharp increase in roughness of machined surface

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Feed. When the work is performed at the greatest technologically permissible feeds, the machine operation time is at its minimum. The value of the permissible feed, in the cases when necessary to machine a surface to a given finish, is computed by the formula

$$s = \frac{C_H \times H_{max}^{Y_H} \times r^{U_H}}{t^{X_H} \times \varphi^{Z_H} \times \varphi_1^{Z_H}} \text{ millimeters} \qquad (1)$$

where H_{max} is the maximum height of the roughness of the surface in microns; r is the conjugate radius of the rear edges in millimeters; φ is the effective cutting angle (in plan) in degrees; φ_1 is the relief angle (in plan) in degrees.

The numerical values of the coefficient C_H and exponents X_H, Y_H, Z_H, and U_H are given in Table 3.

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Table 3

Metal machined	s in millimeters	C_H *	X_H	Y_H	Z_H	U_H
Steel and steel castings	$\leqslant$ 1.75	0.008	0.30	1.40	0.35	0.70
Steel and steel castings	$\geqslant$ 1.75	0.17	0.12	0.60	0.15	0.30
Cast iron	$\leqslant$ 1.60	0.045	0.25	1.25	0.50	0.75
Cast iron	$\geqslant$ 1.60	0.290	0.12-	0.60	0.25	0.35

* The magnitudes of C_H correspond to the blunting of the cutter bit δ = 2 millimeters; when δ = 0.5 millimeter, the magnitudes of C_H are to be increased by 25 - 35 percent.

To avoid sagging or the obtaining of barrel, instead of cylindrical, shapes in the turning of thin and long parts, the magnitude of the feed must satisfy the inequality

$$s \leqslant \left(\frac{P_{dop\,[add'l]}}{C_z \times t^{x_{pz}} \times H_B^{\,n_{pz}}} \right)^{\frac{1}{Y_{pz}}} \text{ millimeters} \qquad (2)$$

where $P_{dop\,[add'l]}$ is the permissible cutting force in

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kilograms (computed by formulas cited in Table 4; H_B -- hardness expressed in Brinell units. The values of the coefficient C_z and exponents X_{pz}, Y_{pz}, and n_{pz} are given in Tables 35 - 37 below.

In the absence of limitations with regard to the finish and the dimensional precision of the surface to be machined, the maximum permissible feed is established with relation to the strength of the most heavily stressed components of the machine.

The average feed values for the various types of rough-machining operations are given in Tables 5 - 8.

The average feed values for various types of semi-finish machining operations (including grinding), are given in Table 9.

The average feed values when working with grooving and cut-off cutters having a width $\underline{V} = 0.6\ d^{0.5}$ millimeters, are given in Table 10.

Table 4

$P_{dop\,[add'l]} = \frac{768\,EIf}{7L^3}$	$P_{dop\,[add'l]} = \frac{48\,EIf}{l^3}$	$P_{dop\,[add'l]} = \frac{3\,EIf}{L^3}$

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Table 5

Feed in transverse and longitudinal rough-turning and undercutting

Diameter of part (d) in millimeters	Depth of cut t in millimeters			
	Up to 5	5 - 8	8 - 12	12 - 30
	Feed s in millimeters / revolutions			
10 - 18	up to 0.25	------	------	-------
18 - 30	0.20 - 0.50	------	------	-------
30 - 50	0.40 - 0.80	0.30 - 0.60	------	-------
50 - 80	0.60 - 1.20	0.50 - 1.00	------	-------
80 - 120	1.00 - 1.60	0.70 - 1.30	0.50 - 1.00	-------
120 - 180	1.40 - 2.00	1.10 - 1.80	0.80 - 1.50	-------
180 - 260	1.80 - 2.60	1.50 - 2.00	1.10 - 2.00	1.00 - 1.50
260 - 360	2.30 - 3.20	2.50 - 2.80	1.50 - 2.50	1.30 - 2.00
above 360	------	2.80 - 3.50	2.00 - 3.00	1.50 - 2.50

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Notes: (1) In turning soft steels when the workpieces are carried on centers, with the ratio $\frac{L}{D} < 6$ or when the workpieces are carried in chucks, with the ratio $\frac{L}{D} < 2$, it is necessary to have higher feed values. In turning hard steel and cast iron, under some conditions, it is necessary to have lower feed values.

(2) In transverse turning and undercutting, the tabular feed values are to be decreased by 30 - 50 percent.

(3) The feeds are given for those cases, when, after a coarse passage, there will be one or several semi-finish passages.

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Table 6

Feed s in millimeters per revolution for coarse longitudinal and transverse turning and undercutting, with cutter bits tipped with hard titanium-cobalt alloy (Grade T5K10)

Hardness of metal to be machined (H_B=Brinell Units)	Thickness of plates in millimeters					
	1.5 - 3.0	3 - 4.5	4.5 - 6	6 - 8	8 - 10	10- 12
115	0.2 - 0.45	0.45 - 0.7	0.7- 1.2	1.2- 1.8	1.8 - 2.7	2.7 - 3.6
115 - 170	0.15- 0.4	0.4 - 0.6	0.6- 0.95	1.95 - 1.5	1.5 - 2.2	2.2 - 2.8
170 - 230	0.1 - 0.3	0.3 - 0.5	0.5- 0.8	0.8 - 1.25	1.25 - 1.8	1.8 - 2.3
230 - 285	0.1 - 0.26	0.25 - 0.45	0.45 - 0.7	0.7 - 1.1	1.1 - 1.6	1.6 - 2.1
285 - 340	0.08- 0.23	0.23 - 0.4	0.4 - 0.60	0.60 - 1.0	1.0 - 1.4	1.4 - 1.8
340 - 400	0.08-0.2	0.2 - 0.35	0.35 - 0.55	0.55 - 0.9	0.9 - 1.3	1.3 - 1.7

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Notes: (1) When cutter bits reinforced with hard titanium-cobalt alloys (T15K6 and T21K8) are used, feeds are to be decreased by 10 - 20 percent, their maximum value not to exceed 1.5 millimeter per revolution.

(2) When cutter bits reinforced with hard VK8 alloy are used, feeds can be increased by 50 percent, when machining cast iron and non-ferrous metals.

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Table 7

Feed s in millimeters per revolution in rough-boring with cutter bit of circular cross-section (length of cutter l = 5d)

Material machined	Depth of cut d in millimeters	Diameter of cutter bit section d in millimeters						
		10	12	16	20	25	30	40
Steel and Steel Castings	2	$<$ 0.08	$\leqslant$ 0.10	0.08 - 0.20	0.15 - 0.40	0.25 - 0.70	0.50-1.00	----
	3	----	$<$ 0.08	$\leqslant$ 0.12	0.10 - 0.25	0.15 - 0.40	0.20-0.50	0.25 -0.60
	5	----	----	$\leqslant$ 0.08	$\leqslant$ 0.10	0.08 - 0.20	0.12-0.30	0.13 -0.40
Cast iron	2	0.08 - 0.12	0.12 - 0.20	0.25 - 0.40	0.50 - 0.80	0.90 - 1.50	----	----
	3	$\leqslant$ 0.08	0.08 - 0.12	0.15 - 0.25	0.30 - 0.50	0.50 - 0.80	0.90-1.20	----
	5	-----	$\leqslant$ 0.08	0.08 - 0.12	0.15 - 0.25	0.25 - 0.50	0.50-0.70	----

Notes: (1) Soft metals require higher feed values, hard metals -- lower feed values.

(2) In machining parts made of non-ferrous metals, the tabular feeds are to be increased by 20 - 30 percent.

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Table 8

Feed s in rough-boring with cantilever boring bar

Material machined (1)	Boring bar overhang in millimeters (2)	Depth of cut t in millimeters (3)	Boring bar diameter in millimeters				
			50 (4)	60 (5)	70 (6)	80 (7)	100 (8)
Steel and steel castings	300	3	0.30 - 0.70	0.60 - 1.20	-----	----	-----
		5	0.15 - 0.30	0.30 - 0.70	-----	----	-----
		8	0.10 - 0.20	0.15 - 0.40	-----	----	-----
	400	3	0.10 - 0.20	0.25 - 0.60	0.60 - 1.20	----	-----
		5	< 0.10	0.15 - 0.30	0.30 - 0.70	----	-----
		8	----	0.10 - 0.15	0.15 - 0.40	0.30 - 0.60	-----
	500	3	----	0.10 - 0.20	0.25 - 0.60	0.40 - 1.00	------
		5	----	< 0.10	0.15 - 0.30	0.25 - 0.50	0.70 - 1.50
		8	----	----	0.10 - 0.15	0.15 - 0.25	0.50 - 1.00

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Table 8 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Steel and steel castings	750	3	-----	-----	-----	0.10 - 0.20	0.30 - 0.70
		5	-----	-----	-----	$<$ 0.10	0.15 - 0.70
		8	-----	-----	-----	-----	0.10 - 0.20
Cast iron	300	3	0.80- 1.20	-----	-----	-----	-----
		5	0.40 - 0.70	0.90 - 1.20	-----	-----	-----
		8	0.20 - 0.30	0.60 - 0.80	-----	-----	-----
	400	3	0.30 - 0.40	0.70 - 1.00	-----	-----	-----
		5	0.15 - 0.25	0.35 - 0.50	0.80 - 1.20	-----	-----
		8	$\leqslant$ 0.10	0.20 - 0.30	0.50 - 0.70	1.00 - 1.50	-----
	500	3	----	0.50 - 0.80	0.70 - 1.00	-----	-----
		5	----	0.30 - 0.40	0.40 - 0.50	0.70 - 1.00	-----
		8	----	0.15 - 0.25	0.20 - 0.30	0.40 - 0.60	1.00 - 1.50

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Table 8 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cast iron	750	3	-----	-----	0.12 - 0.20	0.25 - 0.40	0.80- 1.20
		5	-----	-----	$\leqslant$ 0.10	0.12 - 0.20	0.50 - 0.80
		8	-----	-----	-----	$\leqslant$ 0.10	0.25 - 0.35

Notes: (1) Higher feed values are to be used for soft metals, lower feed values for hard metals.

(2) In the machining of non-ferrous metals, and also when working with boring bar having a forward and return motion, feed values are to be increased by 20 - 30 percent.

(3) The above tabulated feeds are for cases when the rough-boring operation is to be followed by a semi-finish operation.

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Table 9

Feed s for various types of machine operations

Diameter of machined workpiece d in millimeters	Longitudinal and transverse turning and undercutting with normal cutters		Longitudinal turning with broadnose cutter	Boring with normal cutters		Boring with blades
	Rough	Semifinish	Semifinish	Rough	Semifinish	Semifinish
	Degree of fineness of operation					
	$\nabla_2 - \nabla_3$	$\nabla\nabla_4$	$\nabla\nabla_4$	$\nabla_2 - \nabla_3$	$\nabla\nabla_4 - \nabla\nabla_5$	$\nabla\nabla_4 - \nabla\nabla_5$
	Depth of cut (t) in millimeters					
(1)	over 2 (2)	up to 2 (3)	0.2 - 0.5 (4)	over 2 (5)	up to 2 (6)	0.3 - 1.0 (7)
	Feed s in millimeters per revolution					
up to 30	0.15 - 0.25	0.08 - 0.13	0.30 - 0.80	0.10 - 0.15	0.04 - 0.08	0.15 - 0.25
30 - 50	0.25 - 0.35	0.10 - 0.15	0.70 - 1.50	0.15 - 0.25	0.06 - 0.10	0.20 - 0.40

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Table 9 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
50 - 80	0.30 - 0.45	0.13 - 0.20	1.20 --2.00	0.25 - 0.35	0.08-0.13	0.30- 0.50
80 - 120	0.40 - 0.60	0.18 - 0.25	1.80 - 2.50	0.30 - 0.45	0.10 - 0.15	0.40 - 0.60
120 - 180	0.50 - 0.70	0.20 - 0.30	2.0 - 3.0	0.40 - 0.60	0.12 - 0.18	0.50 - 0.80
180 - 260	0.60 - 0.80	0.25 - 0.35	2.5 - 3.5	0.50 - 0.70	0.15 - 0.20	0.70 - 1.0
260 - 360	0.70 - 1.00	0.30 - 0.45	3.0 - 4.0	0.60 - 0.75	0.18 - 0.25	0.90 - 1.2
above 360	0.90 - 1.20	0.35 - 0.55	3.5 - 5.0	0.70 - 1.00	0.20 - 0.30	1.0 - 1.5

Planing and slotting

Shape of cutter bit (1)	Types of machining (2)	Designation of degree of fineness (3)	Depth of cut t in millimeters (4)	Feed s in millimeters/stroke (5)
Normal	Rough	∇_3	up to 3	0.20 - 0.60
	Semifinish	$\nabla\nabla_4$		0.10 - 0.30

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Table 9 (continued)

(1)	(2)	(3)	(4)	(5)
Broadnose	For subsequent polishing	$\nabla\nabla_4$	0.2 - 0.5	(0.3 - 0.5)V
	Final finish with no subsequent polishing	$\nabla\nabla_5$		(0.2 - 0.3)V

Notes: (1) In machining steel and steel castings in transverse planers and shapers, with high depths of cut, lower feed values are to be used; in machining cast iron in longitudinal planers, with shallow depths of cut, higher feed values are to be used.

(2) Feed values in the case of broadnose cutters are not to exceed 0.3 - 0.4 of the width of cutter V.

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Table 10

Feed s in millimeters per revolution when working with cut-off and grooving cutters

Diameter (d) of workpiece in millimeters	Width of cutter bit V in millimeters	Metal being machined				
		Steel, steel castings, aluminum and magnesium alloys, hardness in Brinell units			Cast iron and non-ferrous metals, hardness in Brinell units	
		up to 150	150 - 230	230 - 340	up to 180	180 - 260
(1)	(2)	(3)	(4)	)5)	(6)	(7)
10 - 18	2	0.07 - 0.09	0.05 - 0.07	0.04 - 0.06	0.09 - 0.12	0.07- 0.10
18 - 30	3	0.09 - 0.11	0.07 - 0.09	0.06 - 0.07	0.12 - 0.15	0.10 - 0.12
30 - 50	3 - 4	0.11 - 0.13	0.09 - 0.11	0.07 - 0.09	0.15 - 0.18	0.12 - 0.15
50 - 80	4 - 5	0.13 - 0.15	0.11 - 0.13	0.09 - 0.11	0.18 - 0.22	0.15 - 0.18
80 - 120	5 - 7	0.15 - 0.18	0.13 - 0.15	0.11 - 0.13	0.22 - 0.25	0.18 - 0.20

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Table 10 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
120 - 180	7 - 8	0.18 - 0.22	0.15 - 0.18	0.13 - 0.15	0.25 - 0.30	0.20 - 0.25
180 - 260	8 - 10	0.22 - 0.25	0.18 - 0.20	0.15 - 0.17	0.30 - 0.35	0.25 - 0.28
260 - 360	10 - 12	0.25 - 0.30	0.20 - 0.25	0.17 - 0.20	0.35 - 0.40	0.28 - 0.32
above 360	12 - 15	0.30 - 0.35	0.25 - 0.28	0.20 - 0.22	0.40 - 0.45	0.32 - 0.38

Notes: (1) In the case of non-rigid bracing of the workpiece and cutter, when a clean finish surface is required, and when the feed is hand-operated, the feed values are to be decreased by 30 - 40 percent. In the case of special cut-off machines, the feed is to be increased by 30 - 40 percent.

(2) To obtain a clean finish surface and to prevent forcing out as the cutter bit penetrates deeper toward the center at half radius of the workpiece being machined, the feed value is to be cut down in two, as compared to its starting value.

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Cooling. For effective turning operations (conventional lathes, faceplate lathes, vertical boring and turning lathes, horizontal boring lathes) on steel, steel castings, malleable cast iron, copper-, aluminum-, and magnesium-alloys, a coolant liquid consisting of a 3 - 5 percent water solution of emulsin may be used. In turning work on light non-ferrous metal alloys, a coolant consisting of a mixture of (petroleum) solar oil and kerosene, or special emulsions, may be used. No coolants are used in the machining of gray iron.

Planing and slotting operations are run without coolant (dry).

Durability of cutters. The economical cutter durability T_{ek} (with centralized grinding and sharpening) is determined from the formula, expressed in minutes:

$$T_{ek} = \frac{1-m}{m} \times \frac{t_s t_{s_s} + t_z t_{s_z} + \frac{t_{s_r}}{n+1}}{t_{s_s}} \quad \text{minutes} \qquad (3)$$

Durability of maximum productivity of cutters ($T_{n.p}$), expressed in minutes, is determined by formula

$$T_{n.p} = \frac{1-m}{m} t_s \quad \text{minutes} \qquad (4)$$

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where m is the index of relative durability; t_s is the time required for changing and setting the cutter (in minutes); ts_s is the cost per minute of the operator's time in kopecks, including overhead; t_z is the time required for grinding and sharpening the cutter bit (in minutes); ts_z is the cost per minute of the grinding operator's time in kopecks, including overhead; ts_r is the cost per cutter bit in kopecks; n is the permissible number of regrindings.

The numerical values of indexes m are cited in Table 11.

The average durability values for cutters with relation to their sizes are cited in Table 12.

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Table 11

Cutter durability indexes (m)

Types of cutters (1)	Machining characteristics and conditions (2)	Durability index (m) for cutters made from: High-speed steel (3)	Hard titanium-cobalt alloys (4)	Hard tungsten-cobalt alloys (5)
	Material machined -- steel, steel castings, malleable iron			
Threading, undercutting and boring	Rough and semifinish machining with cooling	0.125	0.125	0.15
	without cooling	0.100	0.125	0.15
Recessing and cut-off	with cooling	0.250	-----	0.15
	without cooling	0.200	-----	0.15
	Material machined -- gray iron			
Threading, undercutting and boring	Rough and semifinish	0.100	0.125	0.20
Recessing and cut-off	The same	0.150	-----	0.20

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Table 11 (continued)

(1)	(2)	(3)	(4)	(5)
	Material machined -- copper alloys			
All types	Rough and semifinish with cooling and without cooling	0.150	-----	0.20
	Material machined -- aluminum and magnesium alloys			
All types	Rough and semifinish with cooling and without cooling	0.300	-----	0.30

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Table 12

Durability of cutters with relation to size

Material of cutter	Cross section of cutter bit (q) in millimeters				
	16 x 25	20 x 30	25 x 40	40 x 60	60 x 90
	Durability of cutter T_{ek} in minutes				
High-speed steel	60	60	90	120	150
Hard alloy-tipped	90	90	120	150	180

Cutting speed. The cutting speed in external longitudinal turning, and planing on a horizontal planer, is computed by the formula

$$v_T = \frac{C_{v_T}}{t^{X_v} s^{Y_v} \left(\frac{H_B}{200}\right)^{n_v}} \text{ meters/minute} \tag{5}$$

$$C_{v_T} = C \cdot K_{T_v} \cdot K_{M_v} \cdot K_{s_v} \times$$

$$\times K_{sl_v} \cdot K_{q_v} \cdot K_{I_v} \cdot K_{\varphi_v} \cdot K_{\varphi_{1_v}} \cdot K_{G_v} \cdot K_{r_v},$$

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where C_{v_T} is the coefficient characterizing operating conditions; C is the coefficient characterizing the effect of the back-rake angle, front-relief angle, and other factors that did not enter through individual coefficients into the above formula; K_{T_v} is the coefficient characterizing the effect of cutter durability; K_{M_v} is the coefficient characterizing the effect of the metal group classification with relation to composition and heat treatment; K_{S_v} is the coefficient characterizing the condition of the metal; $K_{S\ell_v}$ is the coefficient characterizing the effect of the condition of the work surface; K_{q_v} is the coefficient characterizing the effect of the cross section of the bit; K_{I_v} is the coefficient characterizing the material from which the tool is made; K_{φ_v} is the coefficient characterizing the influence of the effective cutting angle in plan; $K_{\varphi_{1v}}$ is the coefficient characterizing the effect of the relief angle in plan; K_{G_v} is the coefficient characterizing the effect of the geometric parameters of the cutter; K_{r_v} is the coefficient characterizing the effect of the radius of chamfer in the tip of the cutter.

The values of the constant coefficients C_{v_T} and exponents X_v and Y_v are given in Table 13.

The numerical values of the exponent n_v and the value of the coefficient $K_{H_\sigma} = \frac{1}{\left(\frac{H_B}{200}\right)^{n_v}}$, characterizing the effect of hardness (expressed in Brinell units) upon the cutting speed, are given in Table 14.

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Table 13

Numerical values[a] of indexes C_{v_T}, X_v, Y_v.

Material of cutter bit (1)	Material to be machined (2)	Operation characteristics (3)	Operating conditions: with cooling C_{v_T} (4)	with cooling X_v (5)	with cooling Y_v (6)	without cooling C_{v_T} (7)	without cooling X_v (8)	without cooling Y_v (9)
High-speed Tool steel Grade RF1	Steel, steel castings, aluminum and magnesium alloys	$s \leqslant 0.25$ mm/rev.	57.20	0.25	0.33	34.80	0.25	0.50
		$s \geqslant 0.25$ mm/rev.	36.20	0.25	0.66	27.80	0.25	0.66
	Malleable iron	$s \leqslant 0.25$ mm/rev.	32.90	0.20	0.25	28.20	0.20	0.40
		$s \geqslant 0.25$ mm/rev.	28.20	0.20	0.50	24.50	0.20	0.50
	Gray iron and copper alloys	semifinish δ = 2 mm	-----	----	----	22.60	0.15	0.30
		δ = 4 mm	-----	----	----	21.60	0.15	0.40

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Table 13 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hard alloy Grade T15K6	Steel, steel castings, aluminum and magnesium alloys	$s \leqslant 0.3$ mm/rev.	146.3	0.18	0.20	138	0.18	0.20
		$s = 0.3 \div 0.75$ mm/rev	167.2	0.18	0.35	152	0.18	0.35
		$s \geqslant 0.75$ mm/rev.	162.5	0.18	0.45	147.7	0.18	0.45
Hard alloy Grade VK8		$s \leqslant 0.3$ mm/rev	67.8	0.22	0.40	64	0.22	0.40
		$s \geqslant 0.3$ mm/rev	62.7	0.22	0.50	57	0.22	0.50
	Cast iron and copper alloys	$s \leqslant 0.4$ mm/rev	----	----	----	67.3	0.13	0.20
		$s \geqslant 0.4$ mm/rev	----	----	----	59.5	0.20	0.40

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Notes: (1) The values of the coefficients C_{v_T} are given for the machining of metal without surface skin, having a hardness (expressed in Brinell units) H_B = 190, with cutter bits of a 20 x 30 millimeters cross section and a flat front facet, and angles α, γ, λ as per GOST 2320 - 43, with angles $\varphi = 45^\circ$, angle $\varphi_1 = 10^\circ$ (high-speed steel) and 15° (hard-alloy-tipped bits), radius of chamfer [at tip of bit] r = 2 millimeters, and permissible wear on, and durability of, cutter, as per data in Tables 1, 2, and 12.

(2) In machining alloyed steels and steel castings with high-speed steel cutters, when coolants are used, the cutting speed values, computed by formula (5), are to be reduced by 10 percent.

(3) In machining steel, cast iron, and other metals with hard-alloy-tipped tool bits, the use of coolants is not recommended.

(4) When broadnose cutters are used, the cutting speed is to be selected within the limits of 12 - 24 meters per minute.

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Table 14

Values of exponents n_v and coefficients $K_{H\sigma}$

Metal to be machined	Exponent n_v	Hardness H_B									
		90-110	111-130	131-150	151-170	171-190	191-210	211-230	231-250	251-270	271-290
		Correction factor $K_{H\sigma}$									
Carbon steel	-1.0 when $H_B < 130$ 1.75 when $H_B \geqslant 130$	1.62	1.96	1.82	1.45	1.20	1.00	0.85	0.73	0.63	0.55
Alloy steel	1.5	----	----	1.70	1.38	1.18	1.00	0.88	0.77	0.67	0.60
Cast iron and copper alloys	1.75	3.30	2.40	1.82	1.45	1.20	1.00	0.85	0.73	0.63	0.55

Note. If the mechanical properties of the metal are characterized by an ultimate strength σ_b in kilograms per square millimeter, H_B is determined by recalculation.

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The numerical values for the correction factors K_{T_v}, K_{M_v}, K_{C_v}, $K_{C_{r_v}}$, K_{q_v}, K_{I_v}, K_{T_v}, K_{φ_v}, $K_{\varphi_{1_v}}$, K_{r_v} are given in Tables 15 - 24.

Table 15

Values of coefficient K_{T_v}

Durability index m	Durability of cutters T in minutes					
	30	60	90	120	150	180
0.10	1.07	1.00	0.96	0.93	0.91	0.90
0.125	1.09	1.00	0.95	0.92	0.90	0.88
	1.15	1.05	1.00	0.97	0.95	0.93
0.15	1.11	1.00	0.94	0.90	0.87	0.85
	1.18	1.06	1.00	0.96	0.93	0.90
0.20	1.15	1.00	0.92	0.86	0.82	0.80
	1.24	1.08	1.00	0.94	0.90	0.87
0.25	1.19	1.00	0.90	0.83	0.79	0.75
0.30	1.23	1.00	0.88	0.81	0.76	0.72
	1.40	1.14	1.00	0.92	0.86	0.82

Note: The values of the coefficient are computed by the formula

$$K_{T_v} = \left(\frac{T}{T_{ek}}\right)^m, \qquad (6)$$

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where T is the durability (for high-speed steel cutters, T = 60 minutes, for hard-alloy-tipped cutters, T = 90 minutes) expressed in minutes.

Table 16

Values of coefficients K_{C_v}

State of metal	K_{C_v}
Cold-wrought	1.10
Hot-rolled, normalized, and heat-treated (hardening with high tempering)	1.0
Annealed	0.90

Table 17

Values of coefficient K_{q_v}

Cross section of cutter bit in millimeters	K_{q_v}	
	Steel and steel castings	Cast iron and copper alloys
6 x 6.....	0.70	0.89
10 x 10; Ø 10; Ø 12...	0.87	0.93
12 x 12; 10 x 16	0.90	0.95
16 x 16; 12 x 12; Ø 16.	0.93	0.97
20 x 20; 16 x 25; Ø20; Ø25	0.97	0.98
20 x 30; 25 x 25; Ø 30..	1.08	1.0
30 x 30; 25 x 40; Ø 40..	1.04	1.02
30 x 45; 40 x 40.....	1.08	1.04
40 x 60.....	1.12	1.06
60 x 90.....	1.19	1.09

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Note: The values of the coefficients are computed with the aid of formula

$$K_{q_v} = \left(\frac{q}{20 \cdot 30}\right)^{P_v} \qquad (7)$$

For steel and steel castings P_v = 0.08, for cast iron P_v = 0.04.

Table 18

Values of coefficient K_{M_v}

Material to be machined	K_{M_v}
Automatic steel	1.20
Carbon steel C $\leq$ 0.6 percent	1.00
C $>$ 0.6 percent	0.85
Chromium, chrome-nickel, chrome-vanadium, chrome-nickel-vanadium, nickel, nickel-molybdenum, chrome-nickel-molybdenum, chrome-molybdenum-vanadium, molybdenum, chrome-molybdenum, and chrome-nickel-molybdenum steel	1.10
Manganese, chromium-manganese, chrome-manganese-molybdenum, chrome-manganese-	

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Table 18 (continued)

-titanium, chromium-silicon, chrome-silicon-manganese, silicon-manganese, chrome-silicon-molybdenum, chrome-nickel-tungsten, chrome-molybdenum-aluminum and chromium-aluminum steel	0.90
Chromium and tungsten tool steel	0.75
Low and high alloy high-speed high-chrome tool steel, stainless and valve steel	0.65
Hatfield steel	0.50
Malleable cast iron	1.00
Gray cast iron and copper alloys	1.00
Aluminum and silumin	5.00
Duralumin σ_b = (25) [redacted] kilograms per mm^2	6.00
σ_b = 35 kilograms per mm^2	5.00
σ_b = 35 kilograms per mm^2	4.00
Electron σ_b = 16 kilograms per mm^2	6.50

Note: The cutting speed in machining aluminum and magnesium alloys is computed by formula (5), the same way as for carbon steel ($C \leqslant 0.6$ percent) $H_B = 200$, but with the follow-up of the corresponding coefficient K_{M_v}.

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Table 19

The value of coefficient K_{sl_v}

Metal to be machined	Surface condition of workpiece	K_{sl_v}
Steel and steel castings	without scale and after pickling	1.0
	with scale	0.90
Cast iron	without skin	1.0
	with skin, hardness up to $H_B = 160$	0.70
	$H_B = 160 - 200$	0.80
	$H_B > 200$	0.90

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Table 20

Range of application and values of coefficient K_{I_v}

Cutter		Metal to be machined	Range of application	K_{I_v}
Material	Make			
(1)	(2)	(3)	(4)	(5)
High-speed tool steel	RF1	All metals	All types of machining by cutting	1.00
	R			0.95
	RO			0.90
	EI-262			1.00
	EI-184	All metals with a hardness $H_B < 200$	Machining at reduced cutting cycles, or with recessing cutters	0.80
Hard Alloy Tipped	T5K10	Steel and steel castings	Rough variable depth cutting; intermittent cutting	0.75
	T5K6	Steel and steel castings	Rough steady depth cutting. Cut-off and profile turning	0.85
	T15K6	Steel and steel castings	Semifinish turning	1.00
	T15K6y	"	Semifinish turning	1.10
	T15K6c	"	Semifinish turning	1.15

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Table 20 (continued)

(1)	(2)	(3)	(4)	(5)
Hard Alloy Tipped	VK8	Cast iron and bronze	Rough variable depth cutting; intermittent cutting; cut-off and profile turning	1.00
	VK6	Cast iron bronze and plastics	Rough steady depth cutting and semi-finish cutting	1.1

Table 21

Values of coefficients $K_{\varphi_{1v}}$

Material of cutter	Relief angle φ_1 in plan, in degrees				
	10	5	20	30	45
High-speed tool steels	1.00	0.97	0.94	0.91	0.87
Hard alloy-tipped tool steels	1.03	1.00	0.97	0.94	0.90

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Note. The values of the coefficients are computed by formula

$$K_{\varphi_{1v}} = \left(\frac{10}{\varphi_1}\right)^{0,09} \tag{9}$$

in the case of cutters made from high-speed tool steel, and by formula

$$K_{\varphi_{1v}} = \left(\frac{15}{\varphi_1}\right)^{0,09} \tag{10}$$

in the case of cutters made from hard alloy-tipped high-speed tool steel.

Table 22

Values of coefficient K_{φ_v}

Metal to be machined	Material of cutter	Effective cutting angle φ in plan, in degrees			
		30	45	60	90
		Coefficient K_{φ_v}			
Steel, steel castings, aluminum and magnesium alloys	High-speed tool steel.....	1.26	1.00	0.84	0.66
	Hard alloy-(titanium-cobalt)-tipped...	1.13	1.00	0.92	0.81
Cast iron and copper alloys	High-speed tool steel and hard alloy-tipped (VK8)	1.20	1.00	0.88	0.73

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Notes: 1. The values of coefficients are computed by formula

$$K_{\varphi_v} = \left(\frac{45}{\varphi}\right)^{Z_v} \qquad (8)$$

The exponent Z_v has the following values: (a) in the machining of steel, steel castings, aluminum and magnesium alloys with cutters made from high-speed tool steel Z_v = 0.60; with cutters made from titanium-cobalt alloy tipped steel Z_v = 0.30; with cutters made from hard alloy VK8-tipped steel Z_v = 0.45. (b) in the machining of cast iron with cutters made from high-speed steel, hard alloy VK8-tipped, Z_v = 0.45.

2. The values of the coefficients K_{φ_v} given above are for the cases when $s \geqslant$ 0.25 millimeter, and in machining cast iron with hard alloy-tipped high-speed tool steel cutters, the feed $s \geqslant$ 0.3 millimeter.

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Table 23

Values of coefficients K_{r_v}

Conjugate radius of rear facets of cutter r in millimeters	Metal to be machined			
	Steel, steel castings, aluminum and magnesium alloys		Cast iron and copper alloys	
	rough operation	semifinish operation	rough operation	semifinish operation
1	0.94	0.86	0.90	0.94
2	1.00	1.00	1.00	1.0
3	1.03	1.09	1.06	1.03
5	----	1.21	----	1.07

1. The values of these coefficients are computed by formula

$$K_{r_v} = \left(\frac{r}{2}\right)^{U_v} \qquad (11)$$

The values of the exponent U_v were accepted as per tabulation below:

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Metal to be machined			
Steel, steel castings aluminum and magnesium alloys		Cast iron and copper alloys	
rough operation	semifinish operation	rough operation	semifinish operation
0.10	0.20	0.1	0.08

2. In the machining of steel and steel castings, the relationship of values, depicted in Table 23 above, holds true up to r = 4 millimeters. A further increase in the conjugate radius leads to a reduced cutting speed, and only beginning with r = 10 millimeters is the cutting speed [redacted] increased again.

Table 24

Values of coefficients K_{G_v}

The form of the front face of cutter bit as per GOST 2320 - 43	K_{G_v}
Flat	1.00
Radius	1.05
Flat or radius with bevel edge	1.15
Flat with negative front rake angle γ = from -5° to -10°; λ = from $+5^\circ$ to $+12^\circ$	1.20

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The correction coefficients in cutting speed computations, with relation to the value of wear δ of high-speed tool steel cutters, are presented graphically in Figure 1.

Figure 1. Correction coefficient K_{δ_v} in cutting speed computations, with relation to the magnitude of wear δ in high-speed tool steel cutters, when machining steel, steel castings, and malleable cast iron: (1) - turning with cooling and planing without cooling; (2) - cutting-off and recessing with cooling; (3) - cutting-off and recessing without cooling; (4) - turning and planing without cooling.
When machining gray iron: (5) - cutting-off and recessing without cooling; (6) - slotting without cooling; (7) - turning and planing without cooling.

If a given machine tool cannot deliver the required spindle RPM to equal n_{ek}, which number conforms to the efficient cutting speed, the problem of computing the requisite spindle RPM is solved as follows:

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(a) the ratio between "neighboring" numbers of spindle revolutions is calculated:

$$\varphi_n = \frac{n_{k+1}}{n_k} \tag{12}$$

and ratio a of the efficient number of spindle revolutions $n_{\underline{ek}}$ to the nearest smaller number of revolutions n_x that the machine tool is capable of delivering:

$$a = \frac{n_{\underline{ek}}}{n_k} \tag{13}$$

(b) the maximum efficiency-permissible reduction in spindle RPM (a_k) is computed by formula

$$a_k = \left(\frac{m}{1-m} \cdot \frac{m\varphi^{\frac{1-m}{m}} - m}{m-1} \right) \tag{14}$$

or with the aid of Table 25 below.

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Table 25

Maximum efficiency-permissible reduction in spindle RPM

Ratio between the "neighboring" number of spindle RPM	Durability index m			
	0.25	0.15	0.125	0.08
1.12	1.06	1.06	1.06	1.06
1.26	1.13	1.13	1.14	1.14
1.33	1.16	1.17	1.18	1.19
1.41	1.20	1.21	1.22	1.24
1.58	1.28	1.30	1.33	1.36

If the calculations result in $a < a_K$, the nearest smaller number of spindle RPM is to be selected, and when $a > a_K$, the nearest larger number of spindle RPM is to be selected.

The cutting speed of boring $v_{\underline{r}}$ or transverse turning $v_{\underline{p}}$ is computed by formula (5), with subsequent multiplication by the correction coefficient:

$$v_{\underline{r}} = v_{\underline{t}} \times K_{\underline{r}_v} \text{ meters per minute;} \qquad (15)$$

$$v_{\underline{p}} = v_{\underline{t}} \times K_{\underline{p}_v} \text{ meters per minute,} \qquad (16)$$

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where v_t is the cutting speed of external longitudinal turning; K_{r_v} is the coefficient characterizing the effect of the bore hole diameter; K_{p_v} is the coefficient characterizing the effect of operating conditions in transverse turning.

The cutting speed in transverse turning is to be figured by the external diameter being machined.

The values of coefficients K_{r_v} and K_{p_v} are given in Tables 26 and 27.

Table 26

Values of coefficient K_{r_v}

Type of operation	K_{c_v}
External longitudinal turning	1.00
Boring:	
up to Ø 75 millimeters	0.80
up to Ø 76 - 150 millimeters	0.90
up to Ø 151 - 250 millimeters	0.95
Ø > 250 millimeters	1.00

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Table 27

Values of coefficient K_{pv}

Cutting direction and type of cutter		$\frac{d_2 - d_1}{d_2}$			
		0.20	0.60	0.80	1.0
		Coefficient K_{pv}			
Forward cutting with end-cut tool	[Drawing]	0.65	0.68	0.71	0.92
Forward cutting with right-bent tool	["]	0.78	0.80	0.84	1.04
External longitudinal turning	["]	1.00	1.00	1.00	1.00
Forward cutting with left-cut straight tool	["]	1.03	1.05	1.08	1.29
Reverse cutting with right-cut straight tool	["]	1.16	1.18	1.22	1.43
Reverse cutting with undercut tool	["]	1.47	1.49	1.53	1.74

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The cutting speed in operating with cut-off and recessing tools is computed by formula

$$v'_T = \frac{C'_{v_T}}{s^{y_v}\left(\frac{H_B}{200}\right)^{n_v}} \text{ meters/minute} \quad (17)$$

$$C'_{v_T} = C \cdot K_{T_v} \cdot K_{M_v} \cdot K_{C_v} \cdot K_{\underline{sl}_v} \times$$
$$\times K_{\underline{I}_v} \cdot K_{d_v} \cdot K_{h_v} \cdot K_{\underline{st}_v},$$

where K_{d_v} is the coefficient characterizing the effect of the ratio of the difference between the external diameter d_2 and diameter d_1 (to which the machining is done); K_{h_v} is the coefficient characterizing the effect of the depth of the slot; $K_{\underline{st}_v}$ is the coefficient characterizing the effect of the type of machine tool.

For the conditional designations of the remaining factors see formula (5).

The values of the coefficients and exponents in formula (17) are given in Tables 14 - 18, 20, and 28 - 31.

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Table 28

Values of coefficient C'_{v_T} and exponent Y_v

Cutter material	Metal to be machined	Operating conditions			
		with cooling		without cooling	
		Coefficient and exponent			
		C'_{v_T}	Y_v	C'_{v_T}	Y_v
High-speed tool steel RF1	Steel, steel castings, aluminum and magnesium alloys	7.60	0.66	----	----
	Malleable iron	8.10	0.50	----	----
	Gray iron and copper alloys	----	----	8.94	0.40
Hard alloy T15K6-tipped	Steel, steel castings, aluminum and magnesium alloys	41.40	0.35	37.60	0.35
Hard alloy VK8 tipped	Aluminum and magnesium alloys	17.10	0.5	15.50	0.50
	Cast iron and copper alloys	----	----	15.00	0.40

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Notes: (1) The numerical values of the coefficients are for machining metals of a hardness H_B = 190 - 210 with square-nosed tools, and angles α, γ, and φ, as per GOST 2323 - 43, with permissible wear as per data in Tables 1 and 2, and durability as per data in Table 12.

(2) In machining (with cooling) of alloy steels and steel castings with high-speed tool steel cutters, the values for the cutting speeds, computed by formula (17), are to be decreased by 10 percent.

Table 29

Values of coefficient K_{d_v}

Type of machine tool [Drawing]	$\frac{d_2 - d_1}{d_2}$	K_{d_v}
With rotary main motion	1.00	1.00
	0.50	0.97
	0.25	0.93
	0.10	0.89
	$\leqslant$ 0.05	0.86
With reciprocating motion	----	1.00

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Table 30

Values of coefficient K_{h_v}

Type of machine tool	Depth of slot in millimeters	K_{h_v}
Reciprocating main motion	2 - 8	1.46 - 1.05
	10	1.00
	15	0.92
	20	0.87
	40	0.76
Rotary main motion	----	1.00

Note: The values of the coefficient are computed by formula

$$K_{h_v} = \left(\frac{10}{h}\right)^{0.20} \qquad (18)$$

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Table 31

Values of coefficient K_{st_v}

Type of machine tool	K_{st_v}
with rotary main motion	1.00
with reciprocating main motion and reversible toolblock	0.60
same, but with non-reversible toolblock	0.50

Cutting speed for transverse planing and slotting machines is computed by formula

$$v''_{60} = \frac{C''_{v_{60}}}{t^{X''_v} s^{Y''_v} \left(\frac{HB}{200}\right)^{n_v}} \; m/min. \quad (19)$$

$$C''_{v_{60}} = C \cdot K_{T_v} \cdot K_{M_v} \cdot K_{C_v} \cdot K_{r_v} \cdot K_{sl_v} \times$$

$$\times K_{I_v} \cdot K_{\varphi_v} \cdot K_{\varphi_{1_v}} \cdot K_{q_v} \cdot K_{l_v} \cdot K'_{st_v},$$

where K_{l_v} is the coefficient characterizing the effect of the length of stroke and overrun of the cutter. Conditional designations of the remaining factors are to be found in formulas (5) and (17).

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The values of the coefficients and the exponents of formula (19) are given in Tables 14 - 24 above and 32 - 34 below.

Table 32

Values of coefficient K_{l_v}

Length of cutter stroke l_d in millimeters	Length of overrun l_p in millimeters	K_{l_v}
50	35	1.18
75	35	1.09
100	50	1.11
150	50	1.02
200	60	1.00
300	60	0.96
300	75	0.96
500	75	0.87

Note: The values of the coefficient are computed by formula

$$K_{l_v} = \left(\frac{200\, l_n}{60\, l_d}\right)^{0.2} \qquad (20)$$

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Table 33

Values of coefficient $C''_{v_{60}}$ and exponents X''_v and Y''_v

Metal to be machined	$C''_{v_{60}}$	X''_v	Y''_v
Steel, steel castings, aluminum and magnesium alloys	28.60	0.25	0.50
Malleable iron	23.00	0.20	0.40
Gray iron and copper alloys	21.00	0.15	0.40

Notes: (1) The numerical values of coefficients $C_{v_{60}}$ are for machining metals with a hardness H_B = 190 - 210, having no surface skin, with square-nosed RF1 cutters of 20 x 30 millimeters cross section, angles α, γ, and λ as per GOST 2320 - 43, with angle φ = 45°, angle φ_1 = 10° (planing) and 45° (slotting), radius r = 2 millimeters, permissible cutter wear as per data in Table 1, cutter durability as per data in Table 12, operation without cooling, overrun of cutter 60 millimeters, and cutter stroke 200 millimeters.

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(2) Cutting speed in machining with hard alloy-tipped tool bits is computed by formula (5), with subsequent multiplication by a coefficient equal to 0.85.

Table 34

Values of coefficient K'_{st_v}

Type of machine tool	K'_{st_v}
Transverse planing (shaping)	1.0
Slotting, with reversible toolblock	0.75
Same, with non-reversible toolblock	0.60

The components of the cutting force are calculated by the following formulas:

(a) when machining with threading cutters (in turning, boring, planing, and slotting)

$$P_z = C_r t^{X_{pz}} s^{Y_{pz}} H_B^{n_{pz}} \text{ kilograms} \tag{21}$$

$$C_z = C_z \cdot K_M \cdot K_{\varphi_{pz}} \cdot K_{r_{pz}} \cdot K_{\gamma_{pz}} \cdot K_{\delta_{pz}};$$

$$P_y = C_y t^{X_{py}} s^{Y_{py}} H_B^{n_{py}} \text{ kilograms}; \tag{22}$$

$$C_y = C_z K_M \cdot K_{\varphi_{py}} \cdot K_{z_{py}} \cdot K_{\gamma_{py}} \cdot K_{\delta_{py}};$$

$$P_x = C_x t^{X_{px}} s^{Y_{px}} H_B^{n_{px}} \text{ kilograms} \tag{23}$$

$$C_x = C_z K_M \cdot K_{\varphi_{px}} \cdot K_{\gamma_{px}} \cdot K_{\delta_{px}};$$

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(b) when machining with recessing and cut-off cutters (in turning, planing, and slotting)

$$P_z = C_z t^{x_{pz}} s^{y_{pz}} H_B^{n_{pz}} \text{ kilograms;} \quad (24)$$

$$C_z = C_1 K_M \cdot K_{\gamma_{pz}} \cdot K_{\delta_{pz}};$$

$$P_y = C_y B^{x_{py}} s^{y_{py}} H_B^{n_{py}}; \quad (25)$$

$$C_y = C_2 K_M K_{\gamma_{py}} K_{\delta_{py}},$$

where P_z is the vertical component of the cutting force in kilograms; P_y is the component perpendicular to the workpiece axis (radial) in kilograms; P_x is the component parallel to the feed (axial) in kilograms; C_z, C_y, C_x are the coefficients characterizing definite operating conditions; C_1, C_2, C_3 are coefficients characterizing the effect of the backrake angle and other factors, which did not enter through individual coefficients into the above equations; K_M is the coefficient characterizing the effect of the metal group classification with relation to composition and heat treatment; $K_{\varphi_{pz}}$, $K_{\varphi_{py}}$, $K_{\varphi_{px}}$ are the coefficients characterizing the effect of the effective cutting angle measured

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in plan; $K_{r_{pz}}$, $K_{r_{py}}$ are the coefficients characterizing the effect of the cutter nose radius; $K_{\gamma_{pz}}$, $K_{\gamma_{py}}$, $K_{\gamma_{px}}$ are coefficients characterizing the effect of the front relief angle; $K_{\delta_{pz}}$, $K_{\delta_{py}}$, $K_{\delta_{px}}$ are the coefficients characterizing the effect of cutter wear.

The values of the coefficients and exponents in the above formulas are given in Tables 35 - 40 and in Figures 2 and 3.

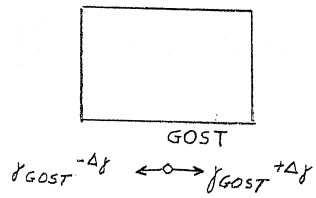

Figure 2. The effect of the front relief angle on the value of coefficient $K_{\gamma_{p(x,y,z)}}$

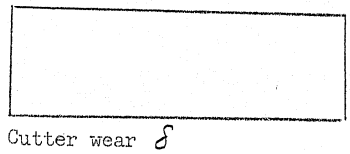

Figure 3. The effect of cutter back face wear on the value of coefficient $K_{\delta_{p(x,y,z)}}$ in machining steel, steel castings, and malleable iron (continuous lines); in machining gray iron (broken lines).

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Table 35

Values of coefficients C_z, C_y, C_x

Cutter types	Cutter material	Metal to be machined: Steel, steel castings, aluminum and magnesium alloys			Metal to be machined: Cast iron and copper alloys		
		C_z	C_y	C_x	C_z	C_y	C_x
Threading	High-speed tool steel	27.90 when $H_B < 170$	0.027	0.022	6.35	0.13	0.16
	Hard alloy-tipped tool steel	3.57 when $H_B > 170$			5.14	0.045	0.051
Recessing and cut-off	High-speed tool steel and hard alloy-tipped	34.42 when $H_B < 170$ 4.42 when $H_B > 170$	0.031	----	8.82	0.12	----

Note. The numerical values of the above coefficients are for tools with angles α, γ, λ, and φ_1

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as per GOST 2323 - 43, $\varphi = 45^{\circ}$, and r = 2 (threading), and cutter wear (δ = 2 millimeters for high-speed tool steel cutters, and δ = 0 millimeters for hard alloy-tipped cutters).

Table 36

Values of exponents of t and s

Cutter types	Metal to be machined											
	Steel, steel castings, aluminum and magnesium alloys						Cast iron and copper alloys					
	X_{pz}	Y_{pz}	X_{py}	Y_{py}	X_{px}	Y_{px}	X_{pz}	Y_{pz}	X_{py}	Y_{py}	X_{px}	Y_{px}
Threading	1.00	0.75	0.90	0.75	1.20	0.65	1.00	0.75	0.90	0.75	1.20	0.65
Recessing and cut-off	1.00	1.00	----	----	1.20	0.75	1.00	1.00	----	----	1.20	0.75

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Table 37

Values of exponents of H_B

Metal to be machined	n_{pz}	n_{py}	n_{px}
Steel and steel castings	0.35 and 0.75*)	2.00	1.50
Cast iron	0.55	1.30	1.10

*) The first value is when $H_B < 170$, the second value -- when $H_B > 170$.

Table 38

Values of coefficient K_M

Metal to be machined	K_M
Hot rolled, annealed normalized and heat treated (hardening with high tempering).....	1.00
Aluminum and silumin	0.20
Duralumin σ_b = 16 kilograms/millimeter.....	0.15
σ_b = 25 kilograms/millimeter.....	0.30
σ_b = 35 kilograms/millimeter.....	0.40
$\sigma_b > 35$ kilograms/millimeter.....	0.55

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Table 39

Values of coefficient K_{φ_p}

Angle φ in degrees	$K_{\varphi_{pz}}$		$K_{\varphi_{py}}$		$K_{\varphi_{px}}$	
	Steel and light non-ferrous alloys	Cast iron and copper alloys	Steel and light non-ferrous alloys	Cast iron and copper alloys	Steel and light non-ferrous alloys	Cast iron and copper alloys
30	1.08	1.05	1.63	1.23	0.70	0.63
45	1.00	1.00	1.00	1.00	1.00	1.00
60	0.98	0.96	0.71	0.87	1.27	1.41
75	1.03	0.94	0.54	0.77	1.51	1.20
90	1.08	0.92	0.44	0.70	1.82	1.28

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Note. The values of the above coefficient are computed by formulas:

$$P_z = C_1 \cdot \varphi^{l_{pz}} ; \tag{26}$$

$$P_y = C_2 \cdot \varphi^{l_{py}} ; \tag{27}$$

$$P_x = C_3 \cdot \varphi^{l_{px}} \tag{28}$$

with the values for the exponents accepted as follows: in machining steel, steel castings and light non-ferrous alloys l_{pz} = - 0.18 (for $\varphi < 55^\circ$) and 0.22 (for $\varphi > 55^\circ$); l_{py} = - 1.2; l_{px} = 0.85; in machining cast iron and copper alloys, l_{pz} = - 0.126, l_{py} = - 0.50, l_{px} = 1.08 (for $\varphi < 45^\circ$) and 0.35 (for $\varphi > 45^\circ$).

Table 40

Values of coefficients $K_{r_{pz}}$ and $K_{r_{py}}$

Radius r in millimeters	$K_{r_{pz}}$		$K_{r_{py}}$	
	Steel, steel castings, aluminum and magnesium alloys	Cast iron and copper alloys	Steel, steel castings, aluminum and magnesium alloys	Cast iron and copper alloys
(1)	(2)	(3)	(4)	(5)
0.5	0.87	0.91	0.65	0.76

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(1)	(2)	(3)	(4)	(5)
1.0	0.93	0.95	0.81	0.87
1.5	0.97	0.98	0.92	0.94
2	1.0	1.0	1.0	1.0
3	1.04	1.03	1.13	1.08
5	1.10	1.07	1.32	1.20

Note. The values of the above coefficients are computed by formulas

$$P_z = C_1 \cdot r^{u_{pz}} \tag{29}$$

$$P_y = C_2 \cdot r^{u_{py}} \tag{30}$$

It being the case that the values for the exponents are accepted as follows: in machining steel, steel castings, aluminum and magnesium alloys, $u_{pz} = 0.10$ and $u_{py} = 0.30$; in machining cast iron and copper alloys, $u_{pz} = 0.07$ and $u_{py} = 0.20$.

Power at the tool. The effective power at the cutter is computed by formula

$$N_e = \frac{P_z \times v_T}{60 \times 102} \quad \text{kilowatt} \tag{31}$$

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or is determined from the nomogram presented in Figure 4.

Gross capacity at machine tool drive is computed by formula

$$N_э = \frac{N_e}{\eta} \text{ kilowatt} \qquad (34)$$

where η is the efficiency factor of machine tool.

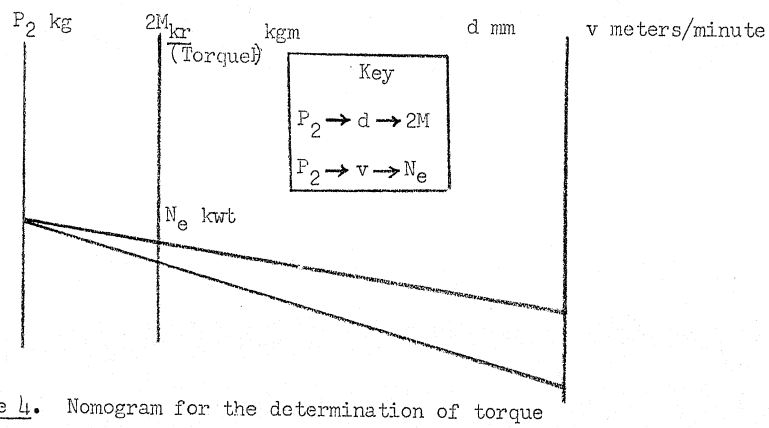

Figure 4. Nomogram for the determination of torque ($2M_{kr}$) and effective power at tool (N_e).

Example: Given d = 100 millimeters, v = 10 meters per minute, P_z = 1000 kilograms;

Derived $2M_{kr}$ = 100 kilograms;

N_e = 1.7 kilowatt.

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Basic (technological) time t_o is computed by formula

$$t_o = \frac{L}{n \cdot s} \cdot \frac{\Delta}{t} \quad \text{minutes,} \qquad (35)$$

where L is the length of travel by cutter (workpiece) in the direction of the feed ($L = l + l_1 + l_2$, or $L = B + l_1 + l_2$ millimeters), which is derived as the sum of length l (in machine tools with rotary main motion), or of width B (in machine tools with rectilinear main motion) of the workpiece part being machined, of the cutter bite l_1, of the approach and receding of the cutter l_2; n -- the number of revolutions per minute of workpiece (or cutter) or the number of double strokes of the cutter (or table) per minute; Δ is the surplus stock for machining in millimeters.

The value for the cutter bite l_1 is computed by formula

$$l_1 = \frac{t}{\tan \varphi} \quad \text{millimeters}$$

The value for the approach and the receding of cutter l_2 is accepted, depending on the depth of cut, up to 3 millimeters.

The combined value for the approach, bite, and receding of an undercutting, recessing, or cut-off tool ($l_1 + l_2$) is accepted as equal to 2 - 5 millimeters.

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The values for the overrun of the cutter (slide block), or of the table, in the case of planers and slotters, are given in Table 41 below.

Table 41

Transverse planer or slotter		Longitudinal planer	
Length of workpiece part being machined in millimeters	Overrun of cutter in millimeters	Length of workpiece part being machined in millimeters	Overrun of table in millimeters
up to 100	35	up to 2000	200
101 - 200	50	2001 - 4000	200 - 300
201 - 300	60	4001 - 6000	300 - 400
over 300	75	6001 -10000	400 - 500

Note. In the case of longitudinal planers equipped with braking devices for purposes of gear shifting, the value for table overrun is to be reduced by 25 percent.

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Cutting Practice for the Machining of Hardened Steels with Hard-Alloy-Tipped Cutters.

Cutter wear. The permissible value of wear δ along the rear facet of hard-alloy-tipped cutters, in the machining of hardened steels, is accepted as 0.8 - 1.1 millimeters.

Tool angles. The optimal geometric parameters of hard-alloy-tipped cutters are given in Table 42.

The main angle measured in plan φ may be reduced by 10 - 15 degrees, and the feed increased correspondingly (the chip thickness is to range between 0.05 - 0.07 millimeters). Such a decrease in the main angle measured in plan makes it possible to increase the cutting speed $\left(\frac{\varphi'}{\varphi''}\right)^{0.5}$ times (2, 3, 6).

Table 42

Ultimate strength in tension σ_b in kg/mm^2	Back rake angle α°	Front angle γ°		Angle in plan		Conjugate radius of rear facets (r in mm.)	Angle of rake of main cutting edge (λ°)
		Hard alloy tip composition		cutting angle φ°	relief angle φ_1°		
		T15K6y	T15K10				
140 - 160		- 10	- 5				
160 - 180	15	- 15	- 10	45 - 90	15	1.0 - 2.0	+ 4
180 - 200		- 20	- 15				

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Depth of cut. When turning hardened steels with hard-alloy-tipped cutters, the depth of cut is to be selected within the range 0.5 - 2 millimeters. Where machining is to be done with great precision, it is rational to remove the entire surplus stock in 2 - 3 passes, with the depth of cut in the last pass to be not more than 0.2 - 0.3 millimeters.

Feed. To attain the minimum machining time, it is necessary to operate at the maximum technologically permissible feeds compatible with the strength of the hard alloy.

The following mean values of feeds for external longitudinal turning are recommended:

Ultimate strength in kg/mm^3 [sic -- should read: in kg/mm^2]:

140 - 160	160 - 180	180 - 200

Feed in mm/revolution:

0.1 - 0.3	0.07 - 0.20	0.05 - 0.015

Cooling. In machining hardened steels with hard-alloy-tipped cutters, no coolants are used.

Durability of cutters. For the determination of the economical durability of cutters T_{ek} and the maximum performance durability $T_{n.p}$ -- see original book pages 79

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and 82. In the machining of hardened steels, the mean value of the exponent of relative durability $m = 0.1$. The mean value of durability $T = 90$ minutes.

Cutting speed in the external turning of hardened steels is computed by formula

$$v_{90} = \frac{C_{v_{90}} \cdot K_{u_{90}} \cdot K_{T_v} \cdot K_{\varphi_v}}{s^{0.47t^{0.33}} \cdot t^{x_v} \cdot \sigma_b^{2}} \qquad (1)$$

where v_{90} is the cutting speed in meters per minute at cutter durability $T = 90$ minutes; C_v is a constant factor; t is the depth of cut in millimeters; s is the feed in millimeters per revolution; σ_b is the ultimate tensile strength in kilograms per square millimeter; K_{u_v} is the coefficient characterizing the effect of the composition of the hard alloy [in the tool bit]; K_{T_v} is the coefficient characterizing the effect of cutter durability; K_{φ_v} is the coefficient characterizing the effect of the main cutting angle measured in plan.

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The numerical values of the coefficient

and the exponent x_v depend on the depth of cut:

t mm.	$C_{v_{90}}$	x_v
up to 1.25	480,000	0.5
1.25 - 2	560,000	1.1

The values of coefficients $C_{v_{90}}$ are given for machining without cooling with square-nosed tools, when angle φ = 45 degrees and the other cutting angles as per Table 42, cutter wear δ = 0.8 - 1.1 millimeters, and cutter durability T = 90 minutes.

The numerical values of coefficients K_{u_v} are accepted to be as follows: when cutter bit is tipped with hard alloy T15K6y used with low feeds and depths of cut, it is K_{u_v} = 1.00; when cutter bit is tipped with hard alloy T5K10 used with high feeds and depths of cut, it is K_{u_v} = 0.75.

Coefficient K_{T_v}, with relation to cutter durability T for these alloys, has the following numerical values:

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Durability T in minutes	30	60	90
Coefficient	1.115	1.040	1.00

Durability T in minutes	120	150	180
Coefficient	0.970	0.950	0.935

With relation to the main cutting angle measured in plan φ, the coefficient K_{φ_v}, in the case of the above hard alloys used in the cutter bit, varies as follows:

Main angle in plan φ°	45	60	75	90
Coefficient K_{φ_v}	1.00	0.88	0.79	0.73

<u>Cutting force.</u> The vertical cutting force is computed by formula

$$P_z = 10.5\, t \cdot s^{0.9} \cdot \sigma_b^{0.75} \quad \text{kilograms} \qquad (2)$$

When cutter wear δ = 1 millimeter, the value of P_z is increased by 5 - 8 percent.

The correlationship between the feeding force P_x, radial force P_y, and vertical force P_z, when φ = 45 degrees, is:

$$\frac{P_x}{P_z} = 0.6 \div 0.8 \text{ and } \frac{P_y}{P_z} = 1.3 \div 2.3$$

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The ratio $\frac{P_x}{P_z}$ is smaller for lower depths of cut, and the ratio $\frac{P_y}{P_z}$ is smaller for higher depths of cut and greater front angles.

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Cutting Practice for the Machining of Holes with Drills, Countersinks, Reamers, Countersink Reamers, and Counterbores.

Cutting tool wear. The permissible values and types of wear for drills, countersinks, and reamers are given in Table 43 and Figures 5, 6, 7.

In the machining of steels, there is wear on the back facet of the tool along the main cutting edges. In the machining of steel by reaming, and of cast iron by drilling, countersinking, and reaming, there is wear at the conjugate points of the main and relief cutting edges.

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Table 43

Tool wear

Name of tool	Appearance of wear	Permissible wear δ in mm when machining	
		Steel with cooling	Cast iron without cooling
Drill	See Fig. 5	1.0 - 1.2	0.5 - 1.2
Countersink	See Fig. 6	0.5 - 1.2	0.8 - 1.5
Reamer	See Fig. 7	0.6 - 0.8	0.6 - 0.8

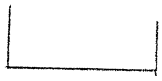

Figure 5

Figure 6

Figure 7

Tool angles. The geometric parameters of the cutting parts of helical drills are determined as per GOST 2322 - 43.

For the geometric parameters of drills, countersinks, and reamers, see Chapter VII.

Depth of cut. When drilling in solid metal, the depth of cut $t = \frac{D}{2}$ (Figure 8).

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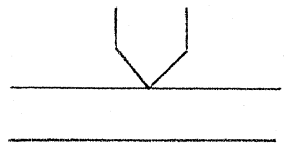
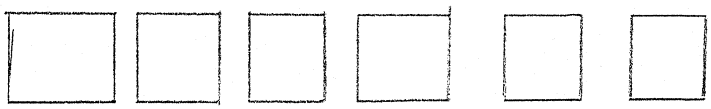


Figure 8.

When oversize drilling, countersinking, reaming, and counterboring, the depth of cut $t = \frac{D - d}{2}$ (Figure 9).



Oversize Drilling | Counter-sinking | Ream-ing | Counter-sink reaming | Counterboring

The amount of surplus stock for countersinking and reaming is discussed in Chapter I.

<u>Feeds in drilling and oversize drilling</u>. The value of the feed in drilling is computed by formula $s = C_s D^{0.6}$, where s is the feed in millimeters per revolution; C_s is the coefficient characterizing the mechanical and technological factors; D is the drill diameter in millimeters.

The values of coefficient C_s are given in Table 44.

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The value of the feed in oversize drilling is 1.2 - 2 times greater than in plain drilling.

The technological factors for various groups of feeds in drilling and in oversize drilling are as follows:

Feed group I (blind-hole drilling): (1) drilling or oversize drilling of a hole, with no tolerance specified; (2) drilling or oversize drilling to 5th class of precision; (3) rough-drilling a hole for subsequent oversize drilling; (4) drilling or oversize drilling of a hole for subsequent machining with 2 or 3 tools (countersink or cutter, and reamers or boring blade); drilling or oversize drilling of a hole for subsequent threading with taps and dies after preliminary machining of hole (immediately following the drilling) with countersink, cutter, or boring blade. In drilling through, for all above enumerated cases, the values of feed are to be selected by group II.

Feed group II (blind-hole drilling and drilling through): (1) the drilling of holes in workpieces, which are inadequately rigid (thin parts of boxlike forms, thin protruding parts of workpiece, and the like); (2) drilling or oversize drilling for subsequent threading of hole with taps and dies or cutter; (3) oversize drilling for subsequent machining of hole with one countersink with normal depth of cut, or with two reamers.

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Feed group III (blind-hole drilling and drilling through): drilling or oversize drilling for subsequent machining of hole with one countersink with shallow depth of cut, or with one reamer.

Table 44

Values of coefficient C_s for the determination of feed in drilling

Metal to be machined and its characteristics		Coefficient C_s		
		Group of feeds determinable by technological factors		
		I	II	III
Steel	H_B up to 160	0.085	0.063	0.042
	H_B=160-240	0.063	0.047	0.031
	H_B=240-300	0.046	0.038	0.023
	H_B above 300	0.038	0.028	0.019
Cast iron	H_B up to 170	0.130	0.097	0.065
	H_B above 170	0.078	0.058	0.039
Non-Ferrous Metals	Soft	0.170	0.130	0.085
	Hard	0.130	0.097	0.065

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Feeds in countersinking. The value of the feed in countersinking is determined by formula

$$s = C_s \times D^{0.6} \quad \text{mm/revolution}$$

where D is the countersink diameter in millimeters; C_s is the coefficient characterizing the mechanical properties and the technological factors pertaining to the metal to be machined.

In machining blind holes, particularly, with the simultaneous machining of the bottom of the hole, the feeds are to be selected within the range 0.2 - 0.6 millimeters per revolution.

The values of coefficient C_s for the determination of feed in countersinking are given in Table 45.

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Table 45

Value of coefficient C_s for

the determination of feed in countersinking

Metal being machined and its hardness characteristic		Values of C_s Group of feeds determinable by technological factors		
		I	II	III
Steel	H_B up to 160	0.190	0.140	0.095
	H_B = 160 - 240	0.140	0.105	0.070
	H_B = 240 - 300	0.105	0.079	0.052
	H_B above 300	0.085	0.063	0.042
Cast iron	H_B up to 170	0.250	0.190	0.125
	H_B above 170	0.150	0.113	0.075
Non-Ferrous Metals	Soft	0.330	0.250	0.170
	Hard	0.250	0.190	0.125

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The technological factors in various groups of feeds in countersinking are as follows:

Feed group I: (1) the countersinking of a hole integral-cast or forged with no tolerance specified; (2) the countersinking of a hole integral-cast or forged provided the hole is to be machined after the rough-countersinking with two or three tools (finish countersink or cutter, and reamers or boring blade); (3) the countersinking of a hole, preliminarily machined by a drill or cutter, with subsequent use of two reamers; (4) the countersinking of a hole integral-cast or forged integrally for subsequent threading with taps and dies or cutter, provided the hole is to be machined, after the rough-countersinking, with a finish-countersink or boring blade.

Feed group II: (1) the countersinking of a hole integral-cast or forged for subsequent threading; (2) the countersinking of a hole integral-cast or forged in accordance with the 5th class of precision; (3) the countersinking of a hole integral-cast or forged for subsequent machining with two reamers; (4) the countersinking of a preliminarily drilled or countersunk hole with the subsequent use of one reamer.

Feed group III: the countersinking of a hole integral-cast or forged for subsequent machining with one shallow cut countersink or one reamer.

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Feeds in reaming. The value of the feed in reaming for passing through is computed by formula

$$S = C_s \cdot D^{0.7} \quad \text{millimeters per revolution}$$

where C_s is the coefficient characterizing the mechanical properties and technological factors of the metal to be machined; D is the diameter of the reamer in millimeters.

The values of the coefficient C_s for the determination of the feed in reaming are given in Table 46.

Table 46

Values of coefficient C_s'' for the determination of feeds in reaming

Metal being machined and its characteristic		Value of C_s''		
		Group of feeds determinable by technological factors		
		I	II	III
(1)	(2)	(3)	(4)	(5)
Steel	H_B up to 160	0.20	0.15	0.10
	H_B = 160 - 240	0.16	0.12	0.08
	H_B above 240	0.12	0.09	0.06

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Table 46 (continued)

(1)	(2)	(3)	(4)	(5)
Cast iron	H_B up to 170	0.33	0.25	0.16
	H_B above 170	0.20	0.15	0.10
Non-Ferrous Metals	Soft	0.20	0.15	0.10
	Hard	0.33	0.25	0.16

The technological factors for various groups of feeds in reaming are:

Feed group I: preliminary (rough) reaming of a hole after drilling or countersinking for subsequent finish-reaming.

Feed group II: (1) finish-reaming as per 2nd class of precision after rough-reaming; (2) finish-reaming to 2nd class of precision after the finish-cut or finish-boring blade.

Feed group III; (1) finish reaming for subsequent polishing or honing; (2) reaming a hole with one reamer to 3rd class of precision.

In the machining of blind holes, particularly, with the simultaneous machining of the hole bottom, the feeds are to be selected within the range of 0.1 - 0.5 millimeters per revolution.

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The coefficients indicated in Tables 44 - 46 are for those cases when the length of the hole does not exceed three times the diameter. When the length of the hole is equal or over three times the diameter, feeds are to be reduced by using the correction factors as per Table 47.

Table 47

Correction factors for the computation of feeds when machining holes exceeding in length three times the diameter

Diameter of hole d in millimeters	Length of hole ℓ expressed in diameters		
	3 - 5	5 - 7	7 - 10
	Feed correction factor		
Up to 20	0.90	0.85	0.80
Up to 40	0.90	0.80	0.75
Up to 60	0.85	0.80	0.75

The value of feeds in countersink reaming and in counterboring are given in Table 48.

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Table 48

Feeds in countersink reaming and counterboring

Diameter of hole D in millimeters	Metals to be machined		
	steel $H_B < 180$, copper and brass	Steels $H_B \geqslant 180$	Cast iron, bronze, and aluminum alloys
	Feed s in mm/ per revolution		
15	0.08-0.12	0.05-0.08	0.10-0.15
20	0.08-0.15	0.05-0.10	0.10-0.15
30	0.10-0.15	0.06-0.10	0.12-0.20
40	0.12-0.20	0.08-0.12	0.15-0.25
50	0.12-0.20	0.08-0.15	0.15-0.25
60	0.15-0.25	0.10-0.18	0.20-0.30
70	0.15-0.25	0.10-0.20	0.20-0.35
80	0.20-0.30	0.12-0.25	0.25-0.40
90	0.20-0.30	0.12-0.25	0.25-0.40
100	0.20-0.30	0.15-0.30	0.25-0.50

Cooling. In machining steels, brass, duralumin, and silumin, the use of lubricating-cooling liquids is obligatory. The rate of consumption of the liquid is to be no less than 6 liters/ per minute.

Table 49 enumerates the liquids recommended for use.

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Table 49

Cooling-lubricating liquids

Metals to be machined	Type of operation	
	Drilling, countersinking, countersink reaming, and counterboring	Reaming
	Liquid to be used	
Carbon-, alloy-, and tool-steels, and steel castings	1. Emulsion 2. "Coupled" oil	1. Emulsion 2. Vegetable oil 3. Coupled oil
Cast iron, bronze	1. Dry 2. Kerosene 3. Mixture of borax and water with glycerin	1. Dry 2. Coupled oil
Duralumin, Silumin	1. Emulsion 2. Rapeseed oil with kerosene	1. Rapeseed oil 2. Kerosene 3. Turpentine

Durability of cutters. To insure minimum cost of machining, cutting speeds are selected to conform with the economical durability of the tools.

Table 50 gives the mean values for the economical durability of tools made from high-speed steels, in the machining of steel and cast iron.

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In those cases when the production schedule calls for the use of the same tools in the machining of both steel and cast iron, the mean values for the durability of the tool are to be figured by the material predominant in production. When there is a simultaneous operation with several tools, similar in type, size and material composition, and also when, under the same conditions, there is an operation with multi-spindle machines or heads, the value for durability is to be multiplied by as many times as there are simultaneously operating tools.

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Table 50

Mean values for the durability of tools

Diameter of tool D in millimeters	Twist drills		Solid countersinks		Inserted-blade countersinks		Reamers -- solid and inserted-blade	
	When machining							
	Steel	Cast iron	Steel	Cast iron	Steel	Cast iron	Steel	Cast iron
	Durability of tool in minutes							
2-5	6	12	---	---	---	---	---	---
6-14	10	18	---	---	---	---	---	---
15-19	12	24	12	30	---	---	24	48
20-24	18	30	18	36	---	---	30	54
25-29	25	36	24	42	36	60	42	72
30-34	30	42	24	48	42	70	48	84
35-39	35	55	---	---	50	85	60	120
40-44	45	60	---	---	55	100	72	150
45-49	55	70	---	---	60	120	85	150
50-54	65	96	---	---	70	120	85	180
55-59	85	120	---	---	90	160	100	180
60-69	100	150	---	---	110	200	120	200
70-79	140	210	---	---	130	240	120	220
80-89	---	---	---	---	---	---	180	240
90-100	---	---	---	---	---	---	200	300

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Tool durability and tool force ratios. The formulas for the computation of the cutting speed v in meters per minute, of the feeding force P_x in kilograms, and of the moment of torque M_{kr} in kilograms per millimeter are given in Table 51.

In the formulas cited in Table 51, C_v is the coefficient characterizing the mechanical properties of the metal being machined and of the tool material (tool steel or hard-alloy-tipped tool bits); C_{px}, C_{pz} are coefficients characterizing the mechanical properties of the metal being machined; T is the durability of the tool in minutes of machine operating time; n_v is the exponent.

The values of coefficients C_v, C_{px}, C_{pz} and of exponent n_v, in the machining of various materials, are given in Table 52.

In operating with tools made from steels not indicated in Table 52, the cutting speed varies in conformity with coefficients depicted in Table 53.

The selection of types of tool steels for the operating tools is done in accordance with Table 54.

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In the machining of holes, the length of which is either equal to or exceeds three times its diameter, the following correction factors for the reduction of the cutting speeds are accepted:

Length of hole ℓ expressed in diameters	3 - 4d	4 - 5d
Correction factor	0.9 - 0.8	0.8 - 0.7

Length of hole ℓ expressed in diameters	5 - 6d	6 - 8d	8 - 10d
Correction factor	0.7-0.65	0.65-0.6	0.6-0.5

In countersink reaming and counterboring, with relation to the material to be machined, the following cutting speeds (in meters per minute) are used:

Steel $H_B < 180$	10 - 18
Steel $H_B > 180$	7 - 12
Cast iron (high degree of hardness)	7 - 12
Cast iron (average hardness) and bronze	12 - 25
Aluminum alloys	40 - 60

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Table 51

Computation formulas

Type of machine operation			Machining of steels, non-ferrous metals and light alloys			Machining of cast iron and bronze		
			Formulas for the determination of the					
			Cutting speed v in meters/min	Axial force P_x in kgms	Moment of torque $M_{\underline{kr}}$ in kgms	Cutting speed v in meters/min	Axial force P_x in kgms	Moment of torque $M_{\underline{kr}}$ in kgms
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Drilling	Tool steel drills	Ø 2-8 mm	$v = \frac{C_v \cdot D^{0.45^1}}{T^{0.2} \cdot S^{0.8} \cdot H_B^{n_v}}$	$P_y = C_{pk} \cdot D \cdot S^{0.7} \times H_B^{0.75}$	$M_{\underline{kr}} = C_{pz} \cdot D^2 \times S^{0.8} \cdot H_B^{0.7}$	$v = \frac{C_v \cdot D^{0.6}}{T^{0.125} \cdot S^{0.75} \cdot H_B^{1.3}}$	$P_y = C_{pk} \cdot D \times S^{0.8} \cdot H_B^{0.6}$	$M_{\underline{kr}} = C_{pz} \cdot D^{1.9} \times S^{0.8} \cdot H_B^{0.6}$
		Ø10-60mm	$v = \frac{C_v \cdot D^{0.4^2}}{T^{0.2} \cdot S^{0.5} \cdot H_B^{n_v}}$			$v = \frac{C_v \cdot D^{0.25}}{T^{0.125} \cdot S^{0.4} \cdot H_B^{1.3}}$		

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Table 51 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Drilling	Hard alloy VK8 (RE8) Blade drills	Ø 12-36 mm	----	----	----	$v = \frac{C_v \cdot D^{0.5}}{T^{0.4} \cdot s^{0.5} \cdot H_B^{1.3}}$	$P_y = C_{py} \times D^{0.75} \cdot s^{0.85} \times H_B^{0.6}$	$M_{kr} = C_{pz} \times D^{2.4} \cdot s \cdot H_B^{0.6}$
Oversize drilling			$v = \frac{C_v \cdot D^{0.4}}{T^{0.2} \cdot s^{0.5} \cdot t^{0.2} \cdot H_B^{n_v}}$	$P_y = C_{py} \cdot s^{0.7} \times t^{1.3} \cdot H_B^{0.75}$	$M_{kr} = C_M \times D \cdot s^{0.8} \cdot t^{0.9} \times H_B^{0.7}$	$v = \frac{C_v \cdot D^{0.25}}{T^{0.125} \cdot s^{0.4} \cdot t^{0.1} \cdot H_B^{1.3}}$	$P_y = C_{py} \times s^{0.4} \cdot t^{1.2} \cdot H_B^{0.6}$	$M_{kr} = C_{pz} \cdot D \times s^{0.8} \cdot t^{0.75} \cdot H_B^{0.6}$
Countersinking with solid and inserted-blade countersinks	Tool steel countersinks		$v = \frac{C_v \cdot D^{0.3}}{T^{0.3} \cdot s^{0.5} \cdot t^{0.2} \cdot H_B^{n_v}}$	—	—	$v = \frac{C_v \cdot D^{0.2}}{T^{0.125} \cdot s^{0.4} \cdot t^{0.1} \cdot H_B^{1.3}}$	—	—
	Hard alloy VK8 (RE8) Blade countersinks		—	—	—	$v = \frac{C_v \cdot D^{0.4}}{T^{0.4} \cdot s^{0.45} \cdot t^{0.1} \cdot H_B^{1.3}}$	—	—

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Table 51 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Reaming		---	---	---	$v = \frac{C_v \cdot D^{0.2}}{T^{0.3} \cdot s^{0.5} \cdot t^{0.1} \cdot H_B^{1.3}}$	---	---

Note: In the machining of low-carbon steel, when $H_B < 155$, the formula is as follows:

1) $v = \frac{C_v \cdot D^{0.65} \cdot H_B^{n_v}}{T^{0.2} \cdot s^{0.8}}$ meters per minute 2) $v = \frac{C_v \cdot D^{0.4} \cdot H_B^{n_v}}{T^{0.2} \cdot s^{0.5}}$ meters per minute.

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Table 52

Values of coefficients C_v, C_{px}, C_{pz} and exponent n_v

Metals to be machined	For all types of operations	Drilling: with high-speed RF1 and EI-262 drills: Drill Ø's up to 10 mm			Drilling: with high-speed RF1 and EI-262 drills: Drill Ø's 10 mm and over			Drilling: Drills with hard alloy VK8 (RE8) blades			Oversize drilling with high-speed RF1 and EI-262 steel drills			Countersinking: Steel RF1 and EI-262 high-speed countersinks		Countersinking: Countersinks with hard alloy VK8 (RE8) blades		Reaming with EI-262 steel reamers
														Solid	Insert blades	Solid	Insert blades	
	n_v	C_v	C_{px}	C_{pz}	C_v	C_{px}	C_{pz}	C_v	C_{px}	C_{pz}	C_v	C_{px}	C_{pz}	C_v	C_v	C_v	C_v	C_v
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Structural carbon steel, ductile, H_B up to 155	0.9	0.041	1.5	0.8	0.10	1.5	0.8	---	---	---	0.168	0.62	1.83	0.226	0.20	---	---	0.152

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Table 52 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Automatic steel, easily machinable, H_B=140-230	0.9	340	1.35	0.72	1310	1.35	0.72	----	----	----	2175	0.56	1.65	3000	2700	----	----	1960
Medium-carbon steel, H_B = 155-265.....	0.9	360	1.5	0.8	874	1.5	0.8	----	----	----	1450	0.62	1.83	2000	1800	----	----	1310
Structural alloy steel: chromium; chromium-nickel; chromium-nickel -molybdenum-vanadium; molybdenum; nickel-molybdenum;																		

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Table 52 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
chromium-vanadium; chromium-molybdenum-vanadium, H_B = 155 - 340	0.9	306	1.8	0.96	743	1.8	0.96	----	----	----	1230	0.74	2.2	1700	1535	----	----	1110
Structural alloy steel: manganese; silicon-manganese; chromium-aluminum; chromium-molybdenum-aluminum; chromium-silicon-molybdenum; chromium-manganese;																		

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Table 52 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
chromium-manganese-molybdenum; chromium-manganese-titanium; chromium-nickel-tungsten, H_B = 155 - 340	0.9	252	1.8	0.96	612	1.8	0.96	----	----	----	1015	0.74	2.2	1400	1260	----	----	915
Carbon tool and carbon hard-machinability steels 50,85, and others, H_B = 155-340..	0.9	270	1.65	0.87	655	1.65	0.87	----	----	----	1090	0.68	2.00	1500	1350	----	----	980

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Table 52 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Tungsten steel H_B = 210-240...	----	1.43	100	40	3.5	100	40	----	----	----	5.8	41	95	8.0	7.2	----	----	5.25
Cobalt tool, alloy tool, and austenitic stainless, heat-resisting, and Hadfield steels, H_B = 210-240...	----	1.15	100	40	2.8	100	40	----	----	----	4.65	41	95	6.4	5.75	----	----	4.2
Brass.....	----	8.6	----	----	21	----	----	----	----	----	35	----	----	48	43	----	----	----
Duralumin, Silumin, Aluminum.....	----	14.3	----	----	35	----	----	----	----	----	58	----	----	80	72	----	----	----

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Table 52 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Electron.....	----	17.2	----	----	42	----	----	----	----	----	70	----	----	96	86	----	----	----
Cast iron, H_B = 140-240...	1.3	4000	2.6	1.0	11400	2.6	1.0	33400	7.1	0.263	15600	0.92	3.16	17100	15400	87000	78300	14500
Malleable iron, H_B = 120-200...	1.3	5000	2.6	1.0	14200	2.6	1.0	41700	7.1	0.263	19500	0.92	3.16	21400	19000	108700	97900	18100
Bronze (medium)	----	13.0	----	----	37.0	----	----	----	---	----	50	----	----	56	50	----	----	----
Bronze (hard)..	----	6.5	----	----	18.5	----	----	----	----	----	25	----	----	28	25	----	----	----

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Table 53

Correction factors for cutting speeds

Name of tool	Grades of tool steels			
	RF1 EI-262	9KhS	U12A U10A	VK8
	Correction factor			
Drills and countersinks.....	1.0	0.65	0.50	2.2
Reamers.....	1.0	0.6	0.5	----

Table 54

Range of application of tools made from tool steels of various grades and hard-alloy tipped tools

Grade	Range of application
RF1, EI-262	Steel and cast iron, $H_B > 230$
9 Kh S	Steel and cast iron, $H_B = 200 - 230$
U12A, U10A	Steel and cast iron, $H_B = 150 - 180$
VK8	Cast iron of any hardness

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Power at the cutting tool N_e is computed by formula

$$N_e = \frac{M_{kr} \times n}{716200 \times 1.36} \text{ kilowatts,}$$

where M_{kr} is the moment of torque in kilograms (see Table 51); n is the number of revolutions per minute.

The basic (technological) time is computed by formula

$$t_0 = \frac{L}{ns}$$

where L is the computation length in the direction of the feed in millimeters; n is the number of revolutions per minute; s is the feed in millimeters per revolution.

The value of L is determined by formulas as follows: in drilling open holes

$$L = l + \frac{D}{2} \operatorname{cotan} \frac{\alpha}{2} + 3s;$$

in oversize drilling, countersinking, and reaming open holes

$$L = l + \frac{D-d}{2} \operatorname{cotan} \frac{\alpha}{2} + 3s;$$

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in cylindrical countersink reaming and counterboring, $L = h$, where l is the length (depth) of the hole; D is the diameter of the tool; d is the diameter of the preliminarily machined hole; α is the angle at the tip of the drill, or the angle at the apex of the chamfer cone of the countersink and reamer; h is the depth of countersinking or the allowance stock for counterboring.

The overrun of the tool is accepted as equal to 3s.

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CUTTING PRACTICE IN MILLING

Milling Cutter Wear. The permissible values of wear δ along the back facet of various types of milling cutters, made from high-speed steel as well as hard-alloy-tipped tool steel, are given in Table 55.

Tool angles. For the geometric parameters of milling cutters see GOST 2321 - 43, also Chapter VI.

Depth and width of cut. The depth of cut t and its width B, when machining with milling cutters of various types, are shown in Figures 10-12. For tolerances in milling see Chapter 1. ¶ Feeds. The value of feed per tooth s_z in milling various metals at a given machining allowance in one pass, and the correction factors for feed, in relation to operating conditions and the rigidity of the workpiece, operating fixture, and the machine tool itself, are given in Tables 56 and 57.

Cooling. When milling in steels, the use of a coolant liquid is obligatory. A 5 percent solution of "emulsol" in water is used for this purpose. The consumption of coolant is to be no less than 10 liters per minute.

Milling cutter durability. The formula for the economical durability of milling cutters can be located on printed page 79.

The numerical exponents m are cited in Table 58.

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The mean values for the durability of various types of milling cutters are given in Table 59.

Figure 10. Depth and width of cut in operating with disk-type milling cutters: a -- three sides toothed milling cutter; b -- two sides toothed milling cutter.

Figure 11. Depth and width of cut in operating with end milling cutters: a -- milling of a slot; b -- milling of a shoulder.

Figure 12. Depth and width of cut in operating with face milling cutters: a -- depth of cut in non-symmetrical milling; b -- depth of cut in symmetrical milling; c -- milling width (the magnitude of machining stock removed in one pass) when operating with face milling cutter.

Cutting speed. The cutting speed v in milling is computed with the aid of formulas cited in Table 60.

The numerical values of the constant coefficients C_v, K_m, K_φ, and K_i are given in Tables 61 - 64.

The numerical values of cutting speeds and feeds in high-speed milling are given in Table 65.

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Table 55

Milling cutter wear

Type of milling cutter		Cylindrical		Face milling	End milling*		Disk milling	Spline milling	Profile milling	Shaped profile milling
					D < 15mm	D > 15mm				
Type of wear		[Drawing]		[Drawing]	[Drawing]		[Drawing]	[Drawing]	[Drawing]	[Drawing]
Material being machined		Steel	Cast iron	Steel -- cast iron	Steel -- cast iron	Steel -- cast iron	Steel -- cast iron	Steel -- cast iron	Steel -- cast iron	Steel -- cast iron
Permissible wear in millimeters	Rough-milling	0.4-0.6	0.5-0.8	1.5-2.0	0.15-0.2	0.3-0.5	0.4-0.6	0.15-0.20	0.6-0.7	0.3-0.4
	Finish milling	0.15-0.25	0.2-0.3	0.3-0.5	0.1 -0.15	0.2-0.25	0.15-0.25	----	0.2-0.3	0.2

*In milling with an end milling cutter, when the stock allowance layer is not in excess of 1 millimeter, the wear takes place at the face edge of the milling cutter, and is permissible in rough milling δ = 0.1-0.15 mm, and in finish milling δ = 0.1 millimeter.

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Table 56

Feed per tooth in the milling of ferrous and non-ferrous metals

Type of milling cutter			Milling stock removable in one pass (in millimeters)								
(1)	(2)	(3)	0.5-1.0 (4)	1-2 (5)	2-4 (6)	4-6 (7)	6-8 (8)	8-10 (9)	10-15 (10)	15-30 (11)	over 30 (12)
Disk-three-sides toothed	Solid	Straight tooth	----	0.08 - 0.05	0.05 - 0.04	0.04 - 0.02	0.04 - 0.02	0.02 - 0.015	----	----	----
		Vari-directional teeth	----	----	----	0.06 - 0.04	0.04 - 0.02	0.04 - 0.02	0.03 - 0.015	0.02 - 0.01	----
	Assembled with inserted teeth		----	----	----	0.10 - 0.07	0.07 - 0.04	0.07 - 0.04	0.04 - 0.03	0.04 - 0.03	0.03 - 0.02

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Table 56 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Disk	Slot Milling Size B	up to 2mm	---	0.01 - 0.005	0.01 - 0.005	0.005 - 0.003	---	---	---	---	---
		over 2mm	---	0.02 - 0.015	0.02 - 0.015	0.01 - 0.005	---	---	---	---	---
	Cut-off B over 2 mm		---	---	---	0.03 - 0.02	0.02 - 0.01	0.01 - 0.007	0.007 - 0.004	0.007 - 0.004	0.007 - 0.004
Face Milling		Small tooth	0.12 - 0.10	0.12 - 0.10	0.10 - 0.05	0.05 - 0.03	---	---	---	---	---
		Large tooth	---	---	0.15 - 0.10	0.10 - 0.07	0.07 - 0.04	0.07 - 0.04	0.07 - 0.04	---	---

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Table 56 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Cylindrical		Small tooth	0.08 - 0.05	0.08 - 0.05	0.08 - 0.05	0.05 - 0.03	---	---	---	---	---
		Large tooth	---	---	0.15 - 0.10	0.10 - 0.07	0.07 - 0.04	0.04 - 0.02	---	---	---
End milling with diameter D		up to 4mm	0.015- 0.01	0.012 - 0.01	0.008 - 0.004	---	---	---	---	---	---
		4 - 6mm	0.02 - 0.01	0.02 - 0.01	0.01 - 0.008	0.008 - 0.005					
		6 - 8mm	0.025 - 0.02	0.02 - 0.015	0.015 - 0.01	0.01 - 0.006	0.006 - 0.003	---	---	---	---
		8 -10mm	0.03 - 0.02	0.025 - 0.015	0.02 - 0.01	0.015 - 0.008	0.008 - 0.006	0.006 - 0.003	---	---	---

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Table 56 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
End Milling with diameter D (continued)		10-15mm	0.04 - 0.02	0.04 - 0.02	0.03 - 0.015	0.02 - 0.01	0.01 - 0.008	0.008 - 0.005	0.005 - 0.003	--- ---	--- ---
		15-20mm	0.06 0.04	0.06 - 0.04	0.04 - 0.02	0.04 - 0.02	0.03 - 0.015	0.02 - 0.01	0.02 - 0.01	0.01 - 0.07	---
		20-30mm	0.10 - 0.07	0.10 - 0.07	0.08 - 0.07	0.08 - 0.05	0.05 - 0.04	0.05 - 0.03	0.03 - 0.01	0.01 - 0.008	---
		30-40mm	0.10 - 0.07	0.10 - 0.07	0.10 - 0.07	0.08 - 0.05	0.08 - 0.05	0.05 - 0.03	0.03 - 0.02	0.02 - 0.01	0.02 - 0.01
Profile milling with diameter D	Plain	up to 60 mm	0.06 - 0.04	0.06 - 0.04	0.04 - 0.03	0.03 - 0.02	0.02 - 0.01	0.02- 0.01	0.02 - 0.01	0.01 - 0.008	---
		over 60 mm	0.10 - 0.07	0.10 - 0.07	0.10 - 0.07	0.08 - 0.05	0.06 - 0.04	0.06 - 0.04	0.04 - 0.02	0.02 - 0.01	---

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Table 56 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
End Milling with diameter D (continued)		10-15mm	0.04 - 0.02	0.04 - 0.02	0.03 - 0.015	0.02 - 0.01	0.01 - 0.008	0.008 - 0.005	0.005 - 0.003	--- ---	--- ---
		15-20mm	0.06 0.04	0.06 - 0.04	0.04 - 0.02	0.04 - 0.02	0.03 - 0.015	0.02 - 0.01	0.02 - 0.01	0.01 - 0.07	---
		20-30mm	0.10 - 0.07	0.10 - 0.07	0.08 - 0.07	0.08 - 0.05	0.05 - 0.04	0.05 - 0.03	0.03 - 0.01	0.01 - 0.008	---
		30-40mm	0.10 - 0.07	0.10 - 0.07	0.10 - 0.07	0.08 - 0.05	0.08 - 0.05	0.05 - 0.03	0.03 - 0.02	0.02 - 0.01	0.02 - 0.01
Profile milling with diameter D	Plain	up to 60 mm	0.06 - 0.04	0.06 - 0.04	0.04 - 0.03	0.03 - 0.02	0.02 - 0.01	0.02- 0.01	0.02 - 0.01	0.01 - 0.008	---
		over 60 mm	0.10 - 0.07	0.10 - 0.07	0.10 - 0.07	0.08 - 0.05	0.06 - 0.04	0.06 - 0.04	0.04 - 0.02	0.02 - 0.01	---

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Table 56 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Profile milling with diameter D	Shaped	up to 60 mm	0.08 - 0.05	0.08 - 0.05	0.08 - 0.05	0.06 - 0.04	0.04 - 0.03	0.03 - 0.015	0.02 - 0.01	0.01 - 0.007	---
		over 60 mm	0.10 - 0.07	0.10 - 0.07	0.10 - 0.07	0.08 - 0.05	0.08 - 0.05	0.05 - 0.03	0.03 - 0.02	0.02 - 0.01	---

Notes: 1. In the milling of bronze and cast iron, the values of feed are to be increased 1.5 - 2.0 times with regard to the operating conditions.

2. In rough-milling with a subsequent finishing pass, the value of feed may be increased 1.5 - 2 times, provided the rigidity of the entire system permits same.

3. In finish-milling with face milling cutters equipped with projecting trimming teeth, the value of the feed is computed by the formula $s = 0.09\ H_{max}^{1.25}$ millimeters per revolution, where H_{max} is the maximum height of the surface roughness expressed in microns.

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Table 57

Correction factors for feed when machining with cylindrical, face milling and profile milling cutters

Operating conditions	Correction factors
In rough-milling under conditions of great rigidity	1.5 - 2
Workpieces rigidly braced in fixtures	1.0
Thin-walled workpieces, with small supporting surfaces, which do not insure adequate bracing (end milling cutters with elongated tail)	0.6
When milling width $B < 0.75\ D$ . .	1.0
When milling width $B > 0.75\ D$	0.6 - 0.8

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Table 58

Values of exponent m

Type of milling cutters	Metal to be machined	Exponent m
Face milling, disk-type, spline milling, saw-milling	Steel, brass, and light alloys	0.2
	Cast iron and bronze	0.15
Cylindrical, end milling, and profile milling	Steel, brass, and light alloys	0.33
	Cast iron and bronze	0.25

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Table 59

Durability values for various types of high-speed steel milling cutters

Width of milling cutter B in millimeters	Cylindrical, disk milling, face milling, shaped profile milling (diameter in millimeters)									
	---	30	40	50	60	80	100	130	160	210
	Sharp-pointed milling (diameter in millimeters)									
	30	40	50	60	80	100	130	160	210	290
	Durability T in minutes									
6	40	50	60	70	80	95	115	130	160	225
10	50	60	70	80	95	115	130	160	190	265
20	60	70	80	95	115	130	160	190	205	315
40	70	80	95	115	130	160	190	225	265	350
80	80	95	115	130	160	190	225	265	315	400
160	95	115	130	160	190	225	265	315	400	480
320	115	130	160	190	225	265	315	400	---	---
	End milling cutters (diameter in millimeters)									
---	up to 6	8-10	15	20	30	40	50	---	---	---
	Durability T in minutes									
---	10	15	20	25	30	40	60	---	---	---

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Notes: In machining with measured end milling and disk-type milling cutters durability is to be increased 1.5 - 2 times.

2. In machining with a set of milling cutters, durability is to be increased 1.2 -1.3 times.

3. In machining with carbon- and alloy-steel milling cutters, all tabular values above are to be increased 1.25 - 1.5 times.

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Table 60

Cutting speed computation formulas

Types of milling cutters (1)	Metal to be machined (2)	Formula (3)	Value of exponents X_v (4)	Y_v (5)	Z_v (6)
Face milling, disk-type, spline milling and saw-milling	Steel, brass, and light alloys	$v = \frac{C_v \cdot D^{0.25} \cdot K_i \cdot K_m \cdot K_\varphi}{T^{0.2} \cdot t^{x_v} \cdot s_z^{y_v} \cdot z^{0.1} \cdot B^{z_v}}$	Face milling $X_v = 0.15$ Disk-type and spline milling $X_v = 0.3$	When $s_z < 0.1$ $Y_v = 0.2$ When $s_z > 0.1$ $Y_v = 0.4$	Spline milling $Z_v = 0.2$ Disk-type and face milling $Z_v = 0.1$
	Cast iron and bronze	$v = \frac{C_v \cdot D^{0.2} \cdot K_i \cdot K_m \cdot K_\varphi}{T^{0.15} \cdot t^{x_v} \cdot s_z^{0.4} \cdot z^{0.1} \cdot B^{z_v}}$	Face milling $X_v = 0.10$ Disk-type and spline milling $X_v = 0.5$	------	Spline milling $Z_v = 0.2$ Disk-type and face milling $Z_v = 0.1$

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Table 60 (continued)

(1)	(2)	(3)	(4)	(5)	(6)
Cylindrical, end milling, and face milling	Steel, brass, and light alloys	$v = \frac{C_v \cdot D^{0.45} \cdot K_i \cdot K_m \cdot K_\varphi}{T^{0.33} \cdot t^{0.3} \cdot s_z^{y_v} \cdot z^{0.1} \cdot B^{0.1}}$	-----	When $s_z < 0.1$ $y_v = 0.2$ When $s_z > 0.1$ $y_v = 0.4$	-----
	Cast iron and bronze	$v = \frac{C_v \cdot D^{0.7} \cdot K_i \cdot K_m \cdot K_\varphi}{T^{0.25} \cdot t^{0.50} \cdot s_z^{y_v} \cdot z^{0.3} \cdot B^{0.3}}$	-----	When $s_z < 0.15$ $y_v = 0.20$ When $s_z > 0.15$ $y_v = 0.60$	-----

The values of the indexes in the formulas above: C_v is a constant coefficient; D is the diameter of the milling cutter in millimeters; T is the durability of the milling cutter in minutes; z is the number of teeth in the milling cutter; K_φ is the coefficient characterizing the effect of the main cutting angle measured in plan; K_m is the coefficient characterizing the effect of the metallurgical classification of the metal being machined and its mechanical properties; K_i is the coefficient characterizing the effect of the metal composition of the tool.

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Table 61

Values of coefficient C_v

Type of milling cutter		Steel 45 σ_b = 70 kg/mm^2		Cast iron H_B = 180	
		$s_z > 0.1$	$s_z < 0.1$	machining in "skin"	without "skin"
Face milling	High-speed steel	55	80	23	46.5
	Hard alloy VK8 tipped	---	---	40	80
Disk-type (φ = 90°)	With inserted teeth	60	86	24	48
	Solid - with vari-directional teeth	---	81	22.75	45.5
	Solid - with straight teeth	---	75	21.5	43
Spline milling and saw-milling		---	65	22.5	45
(1)	(2)	(3)	(4)	(5)	(6)

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Table 61 (continued)

(1)	(2)	(3)	(4)	(5)	(6)
Cylindrical type		46	60	$s_z > 0.15$mm 13.5	27
				$s_z < 0.15$mm 28.8	57.6
End milling		---	35	37.5	75
Profile	with sharp outline	---	44	---	---
	with shallow outline	---	53	---	---

Notes: 1. The values of C_v are given for the machining of steel without "skin", with cooling, for milling against the direction of feed, with the main cutting angle measured in plan $\varphi = 90^\circ$, and for permissible tool wear.

2. In milling a predetermined stock allowance in one pass, when a high-degree surface finish is specified, a correction factor $K = 0.8$ is to be applied to the computation.

3. In the milling of steel without cooling, a correction factor $K = 0.5$ is to be applied to the cutting speed computation.

4. In milling in the direction of feed (not in "skin"), a correction factor $K = 1.5$ is to be applied to the cutting speed computation.

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5. In the milling of steel when "skin" is present, a correction factor $K = 0.6 - 0.7$ is to be applied to the cutting speed computation.

Table 62

Values of coefficient K_m

Metal to be machined	Coefficient K_m	Values of coefficient C_m
Carbon steels	$K_m = \frac{C_m 70^{p_v}}{\sigma_b^{p_v}}$ where the values of the exponent become for steels being machined: (a) low-carbon: σ_b = 30-50 kg/mm^2 $p_v = -1$; (b) carbon- and alloy: σ_b = 55-85 kg/mm^2; $p_v = 1$; (c) high alloy: σ_b = 90-140 kg/mm^2; $p_v = 2$.	1.0
Chromium steels		0.8
Chromium-nickel, chromium vanadium, chromo-molybdenum, chromo-nickel-molybdenum, chromium-tungsten-nickel steels		0.75
Chromo-molybdenum-aluminum, manganese, chromium-manganese, and silicon manganese steels		0.70
Chromium-silicon-manganese steels		0.80
Tool steels: carbon-		1.0
alloy-,		0.70
high-speed		0.50

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Table 62 (continued)

Metal to be machined	Coefficient K_m	Values of coefficient C_m
Stainless, heat-resisting, and Hatfield steels		0.40
Brass		3.0
Silumin, duralumin		5.0
Electron		7.0
Gray iron	$K_m = \frac{C_m 180}{H_B}$	1.0
Malleable iron		1.0
Bronze	$K_m = \frac{C_m 180}{H_B}$	3.

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Table 63

Values of coefficient K_i

Metal to be machined	Grade of steel							
	RF1	R	EI-262	EI-184	RO	9KhS	U12A	U10A
Steel $H_B \leqslant 220$	1.00	1.00	1.00	0.85	0.85	0.50-0.60	0.50-0.60	0.50-0.60
Steel $H_B > 220$	1.00	0.85	1.00	----	----	----	-----	----
Cast iron $H_B \leqslant 180$	1.00	1.00	1.00	0.85	0.85	0.50-0.60	0.50-0.60	0.50-0.60
Cast iron $H_B > 180$	1.00	0.85	1.00	----	----	----	----	-----
Non-ferrous metals and light alloys	1.00	1.00	1.00	0.85	0.85	0.50-0.60	0.50-0.60	0.50-0.60

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Table 64

Values of coefficient K_{φ}

Type of milling cutters	Main cutting angle measured in plan (in degrees) φ				
	90	60	45	30	20
Face milling	0.96	1.0	1.06	1.18	1.30
Disk-type (2 sides toothed) and end milling	1.0	1.05	1.10	1.23	1.37

Table 65

Values of cutting speeds and feeds in high-speed milling

Cutting Procedure	Metal to be machined						
	Carbon steel		Alloy steel			Cast iron	
	$H_B \leqslant 200$	$H_B > 200$	$H_B \leqslant 300$	$H_B = 300-400$	$H_B > 400$	$H_B \leqslant 200$	$H_B > 200$
v in meters/minute	200-220	150-180	150-200	110-150	75-100	120-150	100-120
s_z in millimeters	0.1-0.15	0.07-0.15	0.07-0.1	0.07-0.1	0.05-0.08	0.2-0.4	0.15-0.3

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Note: The above indicated cutting procedures are recommended with a tool durability value $T = (1.0-1.5)D$ minutes.

Force ratios and power. The cutting force within the range of normal tool wear (see Table 55) varies to a small degree in relation to the grade of steel and its condition.

The cutting force, when tool is blunted to the point of optimum wear, in the machining of ductile steels, increases by 75 - 90 percent, and in the machining of medium-hard and hard steels and cast iron -- by 20 - 40 percent.

Thus, the cutting force in the milling of ductile steels with blunted cutting edge of tool is increased to a more pronounced degree than in the milling of medium-hard and hard steels.

This circumstance leads to the conclusion that, for practical computations, the cutting force, when milling with blunted edge of tool, does not, within the above indicated range, depend on the quality of the steel being machined.

Investigations pertaining to the cutting force in milling show that the characteristics of the steel being machined affect the value of the cutting force to a relatively insignificant degree. In the particular case of

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steels, characterized by $\sigma_b = 40 \div 106$ kg/mm^2, the cutting force when milling with face milling cutters (sharp cutting edge), only varies within the range of $\pm$ 10 percent, and when working with cylindrical milling cutters -- within the range of $\pm$ 33 percent [4].

The functional relationships for the determination of the peripheral cutting force and power are cited in Table 67.

The numerical values of correlationships between the components (P_n, P_v and P_o) and cutting force P are given in Table 66.

Basic (technological) time. The computation of the basic (technological) time t_o in milling is done with the aid of the formulas depicted in Table 68.

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Table 66

The values of the ratios between the cutting force P and its components

Types of milling cutters	Symmetrical cutting	Non-symmetrical cutting	
		Forward feed	Reverse feed
Face milling: $\frac{t}{D} = 0.4 \div 0.8$ $s_z = 0.1 \div 0.2$ mm	$P_n : P = 0.3 \div 0.4$ $P_v : P = 0.85 \div 0.95$ $P_o : P = 0.5 \div 0.55$	$P_n : P = 0.9 \div 0.6$ $P_v : P = 0.45 \div 0.7$ $P_o : P = 0.5 \div 0.55$	$P_n : P = 0.3 \div 0.15$ $P_v : P = 1.0 \div 0.9$ $P_o : P = 0.5 \div 0.55$
Cylindrical, end milling, disk-type and profile milling: $\frac{t}{D} = 0.05$ $s_z = 0.1 \div 0.2$mm	------	$P_n : P = 1 \div 1.2$ $P_v : P = 0.2 \div 0.3$ $P_o : P = 0.35 \div 0.4$	$P_n : P = 0.8 \div 0.9$ $P_v : P = 0.75 \div 0.8$ $P_o : P = 0.35 \div 0.4$

Table 67

Relationships for the determination of the peripheral cutting force and effective power (when cutting edge is blunted to optimum permissible value)

Metal machined (1)	Type of milling cutter (2)	Peripheral cutting force P in kilograms (3)	Effective power in kilowatts (4)
Steel	Cylindrical, end milling, and face		

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Table 67 (continued)

(1)	(2)	(3)	(4)
Steel	milling in non-symmetrical cutting (when milling cutter axis projects beyond the limits of the width of the workpiece)	$P=68t^{0.86} \times s_z^{0.74} \cdot z \cdot B \times D^{-0.86}$	$N_e=3.5\times10^{-5} n \cdot t^{0.86} \times s_z^{0.74} \cdot z \cdot B \cdot D^{0.14}$
	Face milling in symmetrical cutting (and also in non-symmetrical cutting when the milling cutter axis projects within the limits of the width of the workpiece), disk-type, and saw milling	$P=82t^{1.1} \cdot s_z^{0.8} \times z \cdot B^{0.95} \cdot D^{-1.1}$	$N_e=4.22\times10^{-5} n \cdot t^{1.1} \times s_z^{0.8} \cdot z \cdot B^{0.95} \cdot D^{-0.1}$
	Angular and bi-angular	$P=39t^{0.86} \cdot s_z^{0.74} \cdot z \times B \cdot D^{-0.86}$	$N_e=2\times10^{-5} n \cdot t^{0.86} \cdot s_z^{0.74} \times z \cdot B \cdot D^{0.14}$
	Convex and concave profile milling	$P=47t^{0.86} \cdot s_z^{0.74} \cdot z \times B \cdot D^{-0.86}$	$N_e=2.42\times10^{-5} n \cdot t^{0.86} \times s_z^{0.74} \cdot z \cdot B \cdot D^{0.14}$

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Table 67 (continued)

(1)	(2)	(3)	(4)
	Cylindrical, end milling, and face milling in non-symmetrical cutting (when milling cutter axis projects beyond the limits of the width of the workpiece)	$P = 30t^{0.83} \times$ $\times s_z^{0.05} \cdot z \times$ $\times B \cdot D^{-0.83}$	$N_e = 1.28 \times 10^{-5} n \times$ $\times t^{0.83} \cdot s_z^{0.65} \cdot z \times$ $\times B \cdot D^{0.17}$
Cast iron	Face milling in symmetrical cutting (and also in non-symmetrical cutting, when the milling cutter axis projects within the limits of the width of the workpiece), disk-type, and saw-milling	$P = 50t^{1.14} \times$ $\times s_z^{0.7} \cdot z \times$ $\times B^{0.9} \cdot D^{-1.14}$	$N_e = 2.57 \times 10^{-5} n \times$ $\times t^{1.14} \cdot s_z^{0.7} \times$ $\times z \cdot B^{0.9} \cdot D^{-0.14}$

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Notes: 1. In the milling of aluminum alloys, the peripheral force and the effective power are determined by applying to the computation for milling in steel the correction factor $K = 0.25$.

2. When milling in bronze castings, the peripheral force and effective power are determined by applying to the computation for milling in cast iron the correction factor $K_1 = 0.75$.

3. In high-speed milling with hard-alloy-tipped milling cutters made with negative front rake angles, the determination of the peripheral force and effective power is accomplished by applying to the computation the correction factors K_γ and K_v, which take into account the effect of the front rake angle and the cutting speed upon the cutting force and the effective power.

The numerical values of these correction factors are given in the table below:

Front rake angle of milling cutter	+15°	+10°	+5°	0°	-5°	-10°	-15°	-20°
K_γ	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Cutting speed in meters/minute	50	75	100	125	150	175	200	250
K_v	1	0.98	0.96	0.94	0.92	0.9	0.88	0.85

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[Drawing]

Figure 13. The magnitude of the infeed path l_1' in milling with a cylindrical milling cutter.

[Drawing]

Figure 14. The magnitude of the infeed path l_1'' when milling with a face milling cutter in symmetrical milling.

[Drawing]

Figure 15. The magnitude of the infeed path l_1''' when milling with a face milling cutter in non-symmetrical milling.

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Table 68

Formulas for the computation of the basic (technological) time in milling

Type of milling	Formula of basic (machining) time in minutes	Letter designations
(1)	(2)	(3)
Cylindrical and face milling with longitudinal and transverse feed: (a) cylindrical milling (Figure 13) -- l_1' (b) face (symmetrical) milling (Figure 14) -- l_1'' (c) non-symmetrical milling (Figure 15) -- l_1'''	$t_0 = \frac{l+l_1+l_2}{s_m} i$	l -- length of milling in mm; l_1 -- cutting-in value in mm; l_2 -- receding value in mm; s_m -- feed per minute in mm; i -- number of passes $l_1' = \sqrt{t(D-t)}$ $l_1'' = 0.5(D-\sqrt{D^2-t^2})$ $l_1''' = \sqrt{t(D-t-2e)}$ t -- depth of cut in mm; D -- diameter of milling cutter in mm.
Milling with circular feed of table	$t_0 = \frac{l+l_1}{s_m} i$	When milling along a complete circle, $l = \pi d$, where d is the diameter along the periphery of the surface being milled. In duplicate milling l is the actual length of the surface being milled along the profile of workpiece.

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Table 68 (continued)

(1)	(2)	(3)
Milling of keyways in one pass:		l -- full length of keyway;
		D -- diameter of milling cutter in mm.
(a) keyway enclosed from two sides;	$t_0 = \frac{h}{s_{m.v}} + \frac{l-D}{s_{m.pr}}$	h -- depth of keyway;
		$s_{m.pr}$ -- longitudinal feed per minute in mm;
(b) keyway enclosed from one side;	$t_0 = \frac{l}{s_{m.pr}}$	$s_{m.v}$ -- vertical feed per minute in mm;
(c) keyway open at two sides	$t_0 = \frac{l+0.5D}{s_{m.pr}}$	
Milling keyways with pendular motion feed machines:		$n_{d.kh}$ -- the number of double passes, determinable by formula, $n_{d.kh} = \frac{h}{t}$ where h is the depth of the keyway; t is the deepening of the keyway with each double pass of the milling cutter in millimeters.
(a) keyway enclosed from two sides;	$t_0 = \frac{l-D}{s_{m.pr}} n_{d.kh}$	
(b) keyway enclosed from one side;	$t_0 = \frac{l}{s_{m.pr}} n_{d.kh}$	
(c) keyway open at two sides	$t_0 = \frac{l+0.5D}{s_{m.pr}} \times n_{d.kh}$	

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CUTTING PRACTICE IN THE MILLING

OF STEEL WITH HARD-ALLOY-TIPPED FACE MILLING CUTTERS

Alloys used for milling cutters. Milling cutters are reinforced with carbide-titanium-tungsten alloys with cobalt: grades T5K10 and T15K6y, or T5K10s and T15K6s. The T5K10 alloy has more strength, but is lower in durability as compared to the T15K6y alloys. The T5K10 alloy is used in machining requiring considerable depths of cut and feed values, with variable machining stock allowance, under conditions of non-rigid bracing of the workpiece, which is due to the inadequate rigidity of the machine or the workpiece.

Alloy T15K6y is used in operations with no sharp impacts, under conditions of rigid bracing of the workpiece.

For the milling of steel, either multi-tooth or single-tooth (flying) milling cutters may be used. The use of either type is economical in the machining of semi-hardened and hardened steels ($\sigma_b >$ 130 kilograms per square millimeter) and for the obtaining of particularly fine surface finishes that do not require grinding. Single-tooth milling cutters are usually used under the indicated conditions in low-power machine tools. The

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economical considerations for the use of face milling cutters in all other cases is determined by the machining time computation.

Milling cutter wear. Face milling cutters, in relation to the mechanical properties of the metal being machined, have a variable value of wear δ along the back face (Figure 16).

Figure 16. Wear diagram of milling cutter blade.

The following value of wear is permissible:

Ultimate strength of steel σ_b in kg/mm^2.....	40 - 60	60 - 80	80 - 100
Permissible wear δ in mm.	0.6 - 0.8	0.8 - 0.10	1.0-1.5

Ultimate strength of steel σ_b in kg/mm^2.....	100 - 120	120 - 140
Permissible wear δ in mm.	1.5 - 2.5	2.5 - 3.5

Geometric parameters of the cutting parts of milling cutters (see Figure 17) are given in Table 69 [Table 69 and Figure 17 are in relation to each other].

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View in the direction of Arrow A

View along Section KL

View along Section NN

[Drawing]

View along Section EF

Figure 17. Geometric parameters of a face milling cutter.

Table 69

Milling cutter angles

σ_b in kg/mm^2	Geometric parameters							
	λ	γ for T15K6y	γ for T5K10	α: d_T and α_f	φ°	φ_1°	φ°	f_o in mm.
Up to 80		-10	- 5	20				
80 - 120	+15	-15	-10	15 - 10	60	5	30	1
Above 120		-20	-15	7 - 10				

Depth of cut in milling is determined by the stock allowance for machining. In order to reduce machining time, when power of machine tool is inadequate for the removal of complete stock in one pass at maximum permissible feed, two or three passes are to be employed.

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Precision work is to be conducted in two passes, the roughing pass and the finishing pass.

Feed. In order to attain minimum machining time, with the established durability of milling cutter, it is economical to employ maximum feed values.

In the machining of steels with hard-alloy-tipped milling cutters, the value of the feed is determined by the strength of the cutting edge of the blade.

The following feed values per tooth of milling cutter reinforced with T15K6y hard-alloy blades, are recommended:

Ultimate strength of steel			
σ_b in kg/mm^2	Up to 60	60-80	
Permissible feed per tooth			
S_z in mm/tooth	0.18-0.20	0.18-0.13	
Ultimate strength of steel			
σ_b in kg/mm^2	80-100	100-120	over 130
Permissible feed per tooth			
S_z in mm/tooth	0.13-0.1	0.1-0.075	0.07

When working with T5K10 hard alloy, the indicated feed values are to be increased by 25 percent.

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Cooling in machining with hard-alloy-tipped milling cutters is not recommended.

Durability of milling cutters. For the formula of the economical durability of milling cutters T_{ek} (provided there is central sharpening) see printed page 79.

The numerical values of exponent m are accepted as follows: m = 0.2 for steel with $\sigma_b \leqslant 100$ kg/mm^2; m = 0.25 for steel with $\sigma_b > 100$ kg/mm^2.

The mean value for the conditional durability of milling cutters is accepted as 300 minutes.

Cutting speed in high-speed milling with face milling cutters is computed by formula

$$v_{300} = \frac{C_v \cdot D^{0.2} \cdot K_i \cdot K_{T_v} \cdot K_{m_v} \cdot K_{\sigma_v}}{t^{0.06} \cdot s_z^{y_v} \cdot B^{0.2}} \text{ meters/minute,}$$

where v_{300} is the cutting speed in meters per minute with the durability of milling cutter T = 300 minutes; C_v is a constant factor; D is the diameter of the milling cutter in millimeters; t is the depth of cut in millimeters; s_z is the feed in millimeters per tooth; B is the milling width in millimeters; K_i is the coefficient

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characterizing the type of hard alloy; K_{T_V} is the coefficient characterizing the durability of the milling cutter; K_{σ_V} is the coefficient characterizing the ultimate strength of the metal being machined; K_{m_V} is the coefficient characterizing the metallurgical classification of the metal being machined; y_V is the exponent of feed s_z.

The numerical values of coefficient C_V (when milling in metal with "skin"), of exponent y_V, and of coefficients K_i, K_{T_V}, K_{m_V} are given in Tables 70 - 73.

Table 70

Numerical values of coefficient C_V and exponent y_V of feed

Feed per tooth (s_z in millimeters)			
0.04 - 0.08		0.08 - 0.2	
C_V	y_V	C_V	y_V
209	0.1	98	0.4

Table 71

Numerical values of coefficient K_i

Grade of hard alloy		T15K6y	T5K10	T15Ks
Factor K_i	for $\sigma_b \leqslant 90$ kg/mm^2	1.0	0.75	1.1
	for $\sigma_b > 90$ kg/mm^2	1.0	0.9	1.1

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Table 72

Numerical values of coefficient K_{T_v}

Value of exponent m	Tool durability T in minutes					
	100	200	300	400	500	600
	Value of coefficient					
0.2	1.22	1.09	1.0	0.95	0.91	0.87
0.25	1.32	1.11	1.0	0.93	0.88	0.84

In relation to ultimate strength in tension, coefficient K_{σ_v} is accepted to have the following values:

Ultimate strength σ_b in kg/mm^2	60 - 80	80 - 100	100 - 120	120 - 140
Coefficient K_{σ_v}	1.00	0.69	0.52	0.40

Table 73

Numerical values of coefficient K_{m_v}

Steel being machined		Coefficient K_{m_v}
Carbon steels	$C \leqslant 0.6$ percent	1
	$C \geqslant 0.6$ percent	0.85
Chromium, chromium-nickel, chromium-vanadium, chromium-nickel-vanadium, nickel, nickel-molybdenum, and chromium-nickel-molybdenum steels		1.1

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Table 73 (continued)

Steel being machined	Coefficient K_{m_v}
Manganese, chromium-manganese, chromium-manganese-molybdenum, chromium-manganese-titanium, chromium-silicon, chromium-silicon-manganese, silicon-manganese, chromium-silicon-molybdenum, chromium-nickel-tungsten, chromium-molybdenum-aluminum, and chromium-aluminum steels.....	0.9
Chromium and tungsten tool steels.....	0.75
Low- and high-alloy high-speed, high-chromium tool steels.....	0.65

In relation to the condition of the surface of the workpiece, coefficient K_{sl_v} is taken as 1.17, when the workpiece is without "skin", and as 1.0, when the workpiece has a "skin".

Cutting force is determined by formula

$$P_z = 66 z t^{0.95} \cdot s_z^{0.8} \frac{B^{1.1}}{D^{1.1}} K_{\sigma_r} \cdot K_{v_r} \cdot K_{\delta_r} \cdot K_{\gamma_r},$$

where z is the number of teeth in the milling cutter; t is the depth of the milling cut in millimeters; s_z is feed in

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millimeters per tooth; B is the milling width in millimeters; D is the diameter of the milling cutter in millimeters; K_{σ_r} is the coefficient characterizing the ultimate strength (in tension) of the metal being machined; K_{v_r} is the coefficient characterizing the cutting speed; K_{γ_r} is the coefficient characterizing the front rake angle; K_{δ_r} is the coefficient characterizing the wear of the milling cutter.

The values for the coefficients K_{σ_r}, K_{v_r}, K_{γ_r}, and K_{δ_r} are given in Table 74.

For the effective power in milling and the basic (technological) time see Tables 67 and 68.

Table 74

Numerical values for coefficient K_{σ_r}, K_{v_r}, K_{γ_r}, and K_{δ_r}

Numerical values of coefficient K_{σ_r}

Ultimate strength σ_b in kg/mm^2	60 - 80	80 - 100	100 - 120	120 - 140
Coefficient K_{σ_r}	1	1.15	1.3	1.45

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Table 74 (continued)

Numerical values of coefficient K_{v_r}

Cutting speed v in meters/minute	50	100	150	200	300	400
Coefficient K_{v_r}	1.0	0.955	0.93	0.9	0.875	0.86

Numerical values of coefficient K_{γ_r}

Front rake angle γ in degrees	20	10	0	-10	-20
Coefficient K_{γ_r}	0.89	1.0	1.12	1.26	1.37

Numerical values of coefficient K_{δ_r}

Wear along back face of milling cutter δ in mm	0	0.5	1.0	1.5	2.0	2.5	3.0
Coefficient K_{δ_r}	1.0	1.15	1.25	1.35	1.45	1.55	1.6

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CUTTING PRACTICES IN GEAR CUTTING

Wear in gear-cutting tools. The cutting teeth in gear-cutting tools wear along the back face and the cambered angles.

Table 75 depicts the permissible values of wear δ along the back face of various gear-cutting tools in the rough- and finish-machining of gears.

Tool angles. The values for the basic geometric parameters of gear-cutting tools are given in Table 76.

Table 75

Wear in gear-cutting tools

Name of tool (1)	The outer appearance of wear (2)	Grade of steel for tool (3)	Permissible wear δ in millimeters: in rough-machining (4)	Permissible wear δ in millimeters: in finish-machining (5)
Gear-shaping slotters	[Photo]	RF1, EI-262	0.8 - 1.0	0.06 - 0.1
		EI-184	0.3 - 0.4	0.06 - 0.1
Worm-gear cutting hobs	[Photo]	RF1, EI-262	1.2 - 1.6	0.2 - 0.35
		EI-184	0.8	0.2 - 0.3
Disk-type module gear cutters	[Photo]	RF1, EI-262	0.8 - 1.0	0.2 - 0.3
		EI-184, U12	0.3 - 0.4	0.2 - 0.3

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Table 75 (continued)

(1)	(2)	(3)	(4)	(5)
Disk-type special gear cutters	[Photo]	RF1 EI-262	1.0 - 1.2	-----
Tooth-planing gear cutters (a) for straight-bevel gears	[Drawing]	RF1 EI-262	0.8 - 1.0	0.25 - 0.3
(b) for spiral-bevel gears	Back face [Drawing] Cutting edge	RF1 EI-262	0.3 - 0.6	0.15 - 0.3
Spiral-bevel-gear-cutting hobs	-----	RF1 EI-262	-----	0.6 - 0.8

Table 76

Tool angles of gear-cutting tools

Name of tool	Tool angles	
	Back relief angle α in degrees	Front rake angle γ in degrees
Gear-shaping slotters	6	5
Worm-gear hobs.....	10	0
Disk-type special gear-shaping cutters for roughing.....	10 - 12	5 - 8
Tooth-planing gear cutters for		
(a) straight-bevel gears...	5 - 6	8 - 10
(b) spiral-bevel gears.....	Up to 12	Up to 10

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Depth of cut. Spur gears up to module $M = 2$, and bevel gears up to module $M = 3$ are finish-cut in one pass.

Spur gears of a module $M > 2$, and bevel gears of a module $M > 3$ are cut in two passes. During the roughing pass, teeth of normal height are cut out to the depth of less than two modules.

In those cases when the rigidity of the machine tool does not allow for the cutting through of the indentation between teeth to a depth of two modules in one pass, it is necessary to conduct the roughing operation in two passes. When $M > 15$, the number of passes may have to be more than two, and it is selected in keeping with the full power utilization of the machine.

In the cutting of straight-bevel gears with a large numerical value of module, the roughing operation may require 4 - 5 passes.

Feed. The values of feeds recommended in the cutting of spur gears and splined shafts are given in Table 77.

Cooling. During the roughing passages in the cutting of steel gears the most effective coolants are a 10 percent water solution of emulsol and spindle oil number 3, and during the finishing passages -- "sulphophrezol" type B and P and a 15 - 20 percent solution of emulsion, with the addition of a 4 percent soap solution. In the last case, it

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is necessary to provide rubber gloves for the protection of the operator's hands. No coolants are used in the machining of cast iron gears.

Table 77

Recommended value for feeds in gear cutting (4).
The material machined is steel 45 or 12KhN3; the tool is made from steel RF1 or EI-262.

Machining method	Feed s in mm per one double stroke or one revolution		
	With the module [numerical value]		
	Up to 2	Up to 3	Up to 4
Gear shaping with 3-inch slotter:			
(a) roughing pass.....	0.31	0.32 - 0.5	0.19 - 0.5
(b) finishing pass.....	0.31	0.31	0.38
Gear cutting with single-thread worm hob:			
(a) roughing pass.....	0.8-1.2	4 - 8	2.7 - 8
(b) finishing pass.....	0.8-1.2	1.2	1.4
Splined shaft cutting with worm hobs:			
(a) roughing pass.....	2 - 4	-----	------
(b) finishing pass.....	1.5 - 2.0	-----	------

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Notes: 1. In the roughing passes, the values of feed in gear cutting are determined in relation to the rigidity of the machine tool, and in the cutting of splines -- in relation to the rigidity of the part being machined.

2. In cutting cast iron gears, the values of feeds are to be 1.5 - 2 times greater than the tabular values.

3. In the rough-cutting of gears with multi-thread gear-cutting hobs, the value of feed, indicated for single-thread hobs, is to be divided by the number of threads.

4. In the rough-cutting of steel blanks for straight-bevel gears with disk-type special gear-shaping cutters, feed values are to be taken within the range of 0.14 - 0.18 millimeters per tooth, and in the case of cast iron blanks -- within the range of 0.26 - 0.3 millimeters per tooth.

In order to increase the durability of the gear-shaping slotters in rough machining, it is recommended that the direction of their rotation be changed after 120 - 140 minutes of operation. This usually increases the durability of the tool by 50 - 70 percent. In machining gears with a module M = 6 with worm-gear hobs, it is recommended that, after the normal blunting, the hobs be shifted axially along the arbor 1.5 - 2 spaces. To make this possible, the initial setting of the hob is to be in the ultimate position which will provide for full engagement with the gear blank being

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machined. In the cutting of gears with a module $M = 1 - 1.5$ with standard single-thread worm-gear hobs, it is possible to obtain from 3 to 8 position shifts of the hob, increasing thereby the durability of the hob by practically as many times. In the cutting of gears with a module $M = 4$, the number of hob position shifts runs from 2 to 4.

Cutting speed in the machining of spur gears and splined shafts is computed by formula

$$v = \frac{C_z \cdot z^x \cdot K_i}{T^m \cdot s^x \cdot M^y} \text{ meters/min.}^* \quad (1)$$

*Note: In the cutting of splined shafts, the letter M designates the height of the splines.

The values of the constant coefficients K_i and C_z and of the exponents in this formula are given in Tables 78 and 79.

Tables 80 and 81 contain information data for the determination of the cutting speed in various types of gear-cutting.

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Table 78

Correction factors for the computation of cutting speed of gear-cutting tools made from tool steels of various grades

Name of cutting tool	Grade of steel	Correction factor K_1 for cutting speed
Spur- and bevel-gear-shaping slotters and worm hobs	RF1 EI-262	1.0
	EI-184	0.6
Disk-type module gear-shaping cutters	RF1	1.0
	U12	0.6
	EI-184	0.7
Gleason type cutters	RF1 EI-262	1.0

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Table 79

Numerical values of coefficients and exponents in the cutting speed equation

Type of gears and gear-cutting method	Tool material	Steels 20Kh and 12KhNZ H_B=215	Steel 40Kh H_B=180	Steel 40Kh H_B=240	Steel 45 H_B=200	Steels 20Kh, 40Kh, and 45				Cast iron H_B = 180 - 200				
		C_z	C_z			k	m	x	y	C_z	k	m	x	y
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Gear slotting														
rough operation	EI-184													
δ = 0.4 mm	RF1 and	93	138	52.5	137	0	0.37	0.65	0.67	----	----	----	----	----
δ = 0.8 mm	EI-262	41.6	47.0	----	49.5	0.03	0.22	0.47	0.29	53.9	0.03	0.11	0.26	0.15
finish operation														
δ = 0.04 mm	RF1 and	176	200	----	208	0	0.37	0	0	----	----	----	----	----
δ = 0.10 mm	EI-262	127	148	----	153	0	0.25	0	0	----	----	----	----	----

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Table 79 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Gear cutting with single-thread worm-gear hob														
When M < 8														
Roughing pass														
δ = 0.8 mm	RF1 and	388	494	----	524	0	0.5	0.85	-0.59	99.8	0	0.23	0.38	-0.52
δ = 1.2 mm	EI-262	445	565	----	598	0	0.47	0.88	-0.52	89.5	0	0.21	0.36	-0.58
When M > 8, the first roughing pass to depth 1.4M														
δ = 1 - 1.2M	RF1 and	217	242	----	256	0	0.25	0.25	0.17	----	----	----	----	----
The 2nd roughing pass to depth 0.7M	EI-262													
δ = 1.0-1.2mm		3050	3440	----	3600	0	0.53	0.53	0.35	----	----	----	----	----

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Table 79 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Spline-shaft hobbing δ = 1.0 mm	RF1 and EI-262	78	90.0	----	120	0.37	0	0.5	1.28	----	----	----	----	----

Notes: 1. The computation of cutting speed is made with relation to the normal 3" slotter. When the slotter is of a 4" diameter, the cutting procedure remains the same; the durability of the cutter T is increased by 30 percent.

2. The table above cites the mean values of permissible wear δ along back face of cutter.

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Table 80

Cutting procedures recommended in certain types of gear cutting

Type and method of machine operation (1)	Cutting tool material (Grade of steel) (2)	Cutting speed v in meters/minute when machining: Steel of grade 20Kh, 12KhNZ H_B = 215 (3)	Steel of grade 40Kh H_B = 180 (4)	Steel of grade 45 H_B = 200 (5)	Cast iron H_B=160-180 (6)	Brass (7)	Cutter durability T_{ek} in minutes (8)	Wear along back face of cutter δ in mm (9)
Spur gear cutting with disk-type module cutter								
(a) roughing pass.....	EI-262	22	30	32	25	40	180	0.8
(b) finishing pass.....	RF1	28	38	40	30	60	180	0.3
Preliminary roughing out of bevel-gear teeth with disk-type special milling cutter on a three-spindle machine.....	EI-262	28	30	32	40	----	480	1.0

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Table 80 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Straight-bevel gear cutting with tooth-planing cutter								
(a) roughing pass.....	EI-262	14.0	18.0	20	20	----	180	1.0
(b) finishing pass.....	RF1	16	20	22	22	----	240	0.25
Spiral-bevel gear-cutting with the aid of indexing heads								
(a) roughing pass.....	EI-262	30.0	34	36	30	----	540	0.7
(b) finishing pass.....	RF1	40	40	40	34	----	500	0.15
Tooth face chamfering with the aid of end-milling cutters....	RF1	45	50	60	45	----	30	0.5

Note: Feed per revolution of the four-toothed end-milling cutter in the chamfering of tooth face is 0.3 - 0.6 millimeters.

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Table 81

Cutting procedure in shaving with 7" disk shaver

Metal being machined	Peripheral cutting speed of shaver in meters/min	Longitudinal feed s in mm/revolution	Vertical feed in mm per table stroke	Number of passes i for complete machining with stock allowance of		Shaver durability in production hours between resharpenings	Number of shaver resharpenings
				0.1 mm	0.2 mm		
Steel 12KhNZ	130	0.15	0.02	5 - 6	8 - 10	20 - 30	6 - 8
Steel 40Kh			0.04				
Steel 45	145	0.25	0.05	4	6 - 8	20 - 30	6 - 8
Cast iron		0.4	0.08	4	6 - 8	10 - 15	6 - 8

Note: The number of gears machined in one durability period of shaver fluctuates within the following range: 400 - 600 cast iron gears

800 -1500 steel gears.

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Cutting force and power. The following formulas are recommended for the computation of cutting force and power.

Gear-tooth slotting. Mean cutting force of roughing operation

$$P_{sr} = \sum F_{sr} \cdot K_s \text{ kilograms} \qquad (2)$$

Mean cross-section of chip

$$\sum F_{sr} = \frac{0.5M^2 \cdot s}{z^{0.1}} \, mm^2 \qquad (3)$$

Cutting coefficient: for medium-hard cast iron K_s = 120 - 140 kilograms per square millimeter; for steel σ_b = 40 - 60, K_s = 160 - 180 kilograms per square millimeter; for steel σ_b = 80 - 100, K_s = 300 - 350 kilograms per square millimeter. Feed s in millimeters per double stroke is selected from Table 78. Mean power at slotter

$$N_{sr} = \frac{P_{sr} \cdot v_{sr}}{9000 \cdot 1.36} \text{ kilowatts} \qquad (4)$$

Finishing operation: the approximate amount of power consumed at the slotter is not in excess of 0.5 kilowatt.

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Gear cutting with worm-gear hob. Power consumed at the hob in roughing passes to full depth

$$N_e = \frac{C_p \cdot v \cdot s^x \cdot M^y \cdot q}{4500 \cdot 1.36} \text{ kilowatt;} \qquad (5)$$

in this formula M designates the module of the gear in millimeters when cutting gear teeth, and the diameter of the shaft when cutting out splines; q is the number of threads in hob. The numerical values for C_p, x, and y are given in Table 82.

The basic (technological) time is computed by the following formulas:

When machining with disk slotter

$$t_o = \frac{\pi z \cdot M}{s_n n} i + \frac{h}{s'_n n} \text{ minutes,}$$

where s_n is the circular feed per one double stroke in millimeters; n is the number of double strokes per minute; s'_n is the infeed = 0.1 - 0.35 s_n; h is the height of the tooth being machined; i is the number of tool passes; z is the number of teeth; M is the indexing module.

In cutting spur gears and shaft splines with worm-gear hobs

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$$t_o = \frac{L \cdot z}{n \cdot s_o \cdot q} \quad \text{minutes,}$$

where q is the number of threads in hob; s_o is the feed per one revolution of the gear blank; n is the number of revolutions per minute of hob; L is the length of carriage travel at operation feed.

When working with a disk-type module gear-cutter on a universal milling machine equipped with an indexing head

$$t_o = \frac{L \cdot z}{s_m} + \frac{L \cdot z}{s_{kh}} + \tau \cdot z \quad \text{minutes,}$$

where s_{kh} is the feed per minute of the back stroke, which (in first approximation) is equal to 4000 millimeters per minute; s_m is the feed per minute of the working stroke; τ is the indexing time per tooth (τ = 0.05 minute).

In the cutting of straight-bevel and spiral-bevel gears

$$t_o = \frac{t_m \cdot z}{60} \quad \text{minutes,}$$

where t_m is production time per tooth in seconds recommended by the machine-building plant for the specific type of machine

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tool and the specific machining method. The value of t_m for the 3 - inch and 16-inch Gleason type machines [Gleason Works, Rochester, N.Y. -- Gear Production Machinery] are given in Tables 83 and 84.

Table 82

Numerical values of coefficient C_p and of exponents x and y

Metal being machined	Numerical values of coefficients in formula (5)					
	C_p		x		y	
	Gears	Shafts	Gears	Shafts	Gears	Shafts
Steel 40.....	30	1.83	----	----	----	----
Steel 40Kh.....	24	1.47	0.75	0.65	1.0	1.1
Steel 20Kh and 12KhNZ....	30	1.35	----	----	----	----
Cast iron H_B = 160-180..	11.3	----	0.8	----	1.13	----
Cast iron H_B = 200 -220..	11.3	----	0.8	----	1.37	----

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Table 83

Tooth-cutting time for spiral-bevel gears on special machines (including time for indexing)[7,8]

Rough machining.

Machine	Module of gears being cut	Metal being machined			
		Steel 20Kh, 12KhNZ		Cast iron H_B=190-225	
		Number of teeth in gears			
		$z > 10$	$z < 10$	$z > 10$	$z < 10$
		Time t_m (in seconds per tooth)			
3"	2 - 2.25	4.2	5.1	3.5	4.2
	2.5 - 2.75	6.4	7.6	4.2	5.1
16"	3	5.5	12	5.5	10
	4	6	12	5.5	10
	5	7	12	6	10
	6	12	17.5	9	15
	7	20	32	16	24
	8	34	60	24	45

Note: Durability of hob until resharpening T = 9 hours.

Mean wear in hob teeth along back faces δ = 0.7 millimeters.

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Table 84

Time t_m in seconds for the cutting of one tooth in spiral-bevel gears

Finish-machining.

Module of gear being cut	Metal being machined			
	Steel 12KhNZ and 20Kh		Cast iron H_B=190-225	
	Special cutter head for simultaneous machining of both sides of tooth (driven gears)			
	Machining in one pass (rough and finish)	Finish-machining	Machining in one pass (rough and finish)	Finish-machining
2	17.8	14.6	14.6	14.6
2.5	20.6	20.6	17.8	14.6
3	28.2	24.7	20.6	14.6
3.5	36.9	24.7	24.7	17.8
4	----	32.3	32.3	17.8
5	----	32.3	36.9	20.6
6	----	36.9	----	24.7
7	----	42.2	----	32.3
8	----	71.5	----	42.2

Note: Durability of hob until resharpened T = 10 hours.

Mean wear in hob teeth along back faces δ = 0.25 millimeter.

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In machining with disk shaver (the number of revolutions per minute of shaver $n = 252$, the diameter of the shaver indexing circle $D \approx 175$ millimeters).

$$t_o = \frac{l \cdot i \cdot z}{252 s \cdot z_1} \quad \text{minutes,}$$

where z_1 is the number of shaver teeth $(z_1 = \frac{175}{M})$; i is the number of machine table passes, specified for the machining of the gears; l is the length of a tooth in millimeters; s is the feed per one revolution of the gear blank.

In chamfering the tooth faces with a helical end milling cutter

$$t_o = \frac{\pi D}{s \cdot n} i \quad \text{minutes,}$$

where D is the diameter of the indexing circle of the gear being machined; s is the feed per one revolution of the hob (0.3 - 0.5 millimeters); n is the number of revolutions per minute of the hob ($n = 1580 - 2000$ revolutions per minute); i is the number of passes in the machining of the gear (when M = up to 1-1/2, $i = 1$, when $M = 2$ to 4, $i = 2$, when $M = 5$ to 6, $i = 3$).

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CUTTING PRACTICES IN BROACHING

Wear in broaches. The cutting teeth in broaches wear along the back face and angular passages, and also at the corners of the chip-breaking flutes.

The permissible values of wear δ along the back face of various types of broaches are given in Table 85.

[Drawing]
Figure 18

[Drawing]
Figure 19

[Drawing]
Figure 20

[Drawing]
Figure 21

[Drawing]
Figure 22

[Drawing]
Figure 23

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Table 85

Wear in broaches

Type of broach	General appearance of broach	Appearance of wear	Value of permissible wear δ along back face in mm
Keyway broach	See Figure 18	See Figure 20	0.3 - 0.4
Spline broach	See Figure 19	See Figure 21	0.3 - 0.4
Round (cylindrical) broach	See Figure 22	See Figure 23	0.2 - 0.3

Tool angles. The values of the tool angles, which determine the cutting capacities of the broaches, are given in Table 86.

Table 86

Sharpening angles of broaches

Metal being machined	Back relief angle α°	Front rake angle γ°
Steel	2 - 4	12 - 15
Cast iron	2 - 3	5 - 10
Bronze and aluminum alloys	5 - 6	15 - 20
Brass and soft aluminum alloys	5 - 6	22 - 25

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Feed. The value of feed in broaching, with relation to the actual operating conditions, may be selected from Table 87.

Table 87

The values of feed in broaching

Types of broaches	Feed per tooth (in millimeters)	
	Metal being machined	
	Steel, aluminum and magnesium alloys	Cast iron and copper alloys
Keyway and spline: width of flute up to 6 mm.....	0.05 - 0.08	0.06 - 0.12
width of flute over 6mm.....	0.06 - 0.15	0.08 - 0.2
Round (cylindrical).....	0.02 - 0.04	0.04 - 0.06

Notes: 1. In broaching surfaces with acute angle profile concavities, reduced feed values are to be selected, but no less than 0.02 millimeters per tooth.

2. In the broaching of complex profiles (profile grooves), in which the machining surplus stock is removed

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simultaneously in the depth and the width of the profile (progressive broaching), the value of feed is limited by the strength of the broach, and lower feed values are, therefore, to be selected.

Cooling. The coolant used in broaching of steel workpieces is "sulphophrezol". In the broaching of complex profiles, a 20-percent solution of emulsol in water, with the addition of a 4-percent soap solution, is sometimes used. In this case, rubber glove protection should be furnished for the operator. Cast iron workpieces are broached dry.

Cutting speed in the broaching of external surfaces and holes of various profiles is established by taking into account the following factors: (a) the mechanical properties of the metal being machined (hardness, microstructure, the presence of extraneous inclusions); (b) shape of surface to be machined (the presence of acute internal angles, complexity of profile, length of hole to be broached); (c) the metal of the broach (the presence of special cemented tips or of chemical treatment on cutting profile); (d) cooling.

The cutting speed in broaching is determined by the formula

$$v = \frac{C_v}{T^{X_v} s_z^{Y_v}} K_{i_v} \quad \text{meters per minute,}$$

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where C_v is the coefficient characterizing operating conditions; T is the durability of the broach in minutes of machining time (disregarding the back stroke); s_z is the value of feed per one broach tooth in millimeters; K_{i_v} is the coefficient characterizing the grade of steel from which the broach is made.

The numerical values of coefficient C_v and exponents X_v and Y_v are given in Table 88.

The values of coefficient C_v are given for broaches made from 5KhVS steel. For broaches made from other grades of steel, the numerical values of coefficients K_{i_v} are 1.0 for KhV5 and 5KhVS steels, 1.4 for RF1 steel, and 1.45 for EI-262 steel.

Economical durability in broaching is to be taken as 100 minutes. When other durability values are taken, a cutting speed correction factor K_{T_v} should be introduced as per Table 89.

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Table 88

The value of coefficient C_v and exponents X_v amd Y_v

Metal being machined	Hardness H_B	Types of broaches											
		Cylindrical			Spline			Keyway: When $s_z \leq 0.07$ mm/tooth and $v \leq 11$ meters/min			Keyway: When $s_z = 0.1-0.15$ mm/tooth and $v \geq 8$ meters/min		
		C_v	X_v	Y_v	C_v	X_v	Y_v	C_v	X_v	Y_v	C_v	X_v	Y_v
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Steel 45.....	160 - 180	12	0.62	0.62	11	0.6	0.75	7	0.87	1.4	5.5	0.87	1.4
Steel 45.....	181 - 207	11	0.62	0.62	10	0.6	0.75	6.3	0.87	1.4	5	0.87	1.4
40Kh.....	160 - 190												
20Kh.....	140 - 170												
12KhNZ.....	140 - 170												

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Table 88 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Steel 45	220 - 260												
40Kh.....	200 - 230	8	0.62	0.62	7.3	0.6	0.75	4.5	0.87	1.4	3.6	0.87	1.4
20Kh.....	180 - 220												
12KhNZ.....	180 - 220												
Steel 40Kh.....	290 - 330												
20Kh.....	260 - 290	7	0.77	0.8	5.5	0.5	0.6	3.4	0.87	1.4	2.7	0.87	1.4
12KhNZ.....	260 - 290												
Cast iron	160 - 180	10	0.5	0.6	12.5	0.5	0.6	4.4	0.6	0.95	4.4	0.6	0.95
	190 - 215	8.2	0.5	0.6	10.5	0.5	0.6	3.65	0.6	0.95	3.65	0.6	0.95

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Table 89

Correction factors K_{T_v} taking into account the effect of tool durability on cutting speed

Types of broaches (1)	Metal being machined (2)	Hardness H_B (3)	Tool durability T in minutes of basic production time				
			60 (4)	100 (5)	180 (6)	240 (7)	360 (8)
Cylindrical	Steel 45	160 - 260	1.38	1.00	0.7	0.59	0.45
	20Kh	140 - 220					
	40Kh	160 - 230					
	12KhNZ	140 - 220					
	Steel 20Kh	260 - 290	1.49	1.00	0.64	0.51	0.37
	40Kh	290 - 330					
	12KhNZ	260 - 290					
	Cast iron	160 - 215	1.29	1.00	0.75	0.65	0.53

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Table 89 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Spline	Steel 45	160 - 250	1.38	1.00	0.7	0.59	0.45
	20Kh.	140 - 220					
	40Kh.	160 - 230					
	12KhNZ	140 - 220					
	Steel 20Kh	260 - 290	1.29	1.00	0.75	0.65	0.53
	40Kh	290 - 330					
	12KhNZ	260 - 290					
	Cast iron	160 - 215					
Keyway	Steel 45	160 - 220					
	20Kh	140 - 220					
	when s_z=0.07 mm/tooth with $v \leqslant$ 11m/min		1.56	1.00	0.6	0.47	0.33
	when s_z=0.1-0.15 mm/tooth with $v \geqslant$ 8-11 meters/min. . .		1.14	1.0	0.86	0.8	0.72
	Cast iron	170 - 220	1.38	1.0	0.7	0.59	0.45

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Cutting force in broaching is computed by formulas as follows:

When machining with keyway and spline broaches:

$$P_z = C'_p \cdot s_z^{y_p} \cdot b \cdot q \cdot n \cdot K_\delta \cdot K_{zh} \cdot K_\alpha \cdot K_\gamma$$

When machining with cylindrical broaches:

$$P_z = C''_p \cdot s_z^{y_p} \cdot D \cdot q \cdot K_\delta \cdot K_{zh} \cdot K_\alpha \cdot K_\gamma,$$

where P_z is the cutting force in kilograms; C'_p, C''_p are coefficients characterizing the quality of the metal being machined and other factors; s_z is the value of feed per broach tooth in millimeters; b is the width of the flute or spline in millimeters; q is the number of broach teeth sections in simultaneous operation; D is the broaching diameter in millimeters; n is the number of splines; K_δ is the coefficient characterizing the effect of wear in the cutting edges; K_{zh} is the coefficient characterizing the effect of cooling; K_α is the coefficient characterizing the effect of the back relief angle; K_γ is the coefficient characterizing the effect of the front rake angle.

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The numerical values of coefficients C'_p, C''_p and the exponent of feed y_p are given in Table 90.

The following numerical values of coefficients K_δ, K_α, and K_γ are accepted:

Wear δ in mm	0	0.3	1.0
K_δ	1.00	1.15	1.75
Angle γ°	12	6 - 8	Up to 2
K_γ	1.00	1.13	1.35
Angle α°	2 - 3	Up to 1	
K_α	1.00	1.20 when machining steel	
	1.00	1.12 when machining cast iron	

Table 90

Values of constant coefficients C'_p and C''_p and exponent y_p

Metal being machined	Hardness H_B	C'_p for keyway broaching	C'_p for spline broaching	C''_p for cylindrical broaching	y_p
Steel 45....	160 - 180	177	212	700	0.85
Steel 45....	181 - 207	202	230	762	
40Kh...	160 - 190				
Steel 45...	220 - 260	250	284	842	
40Kh..	200 - 230				
20Kh..	180 - 220				
Steel 40Kh..	290 - 330	282	315	1000	
20Kh..	260 - 290				
Cast iron...	160 - 180	115	152	300	0.73
	190 - 215	137	215	354	

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When the use of "sulphophrezol" as a coolant is required, coefficient $K_{zh} = 1.0$; when a 20-percent water solution of emulsol, with the addition of a 4-percent soap solution, is used as the coolant, coefficient $K_{zh} = 1.34$.

The effective power required for chip removal in broaching is computed by formula

$$N_e = \frac{P_z \cdot v}{60 \cdot 102} \quad \text{kilowatt.}$$

The maximum pulling force of the broaching machine P_{max} is computed by the cutting force P_z exerted in broaching without cooling, and with tool wear value $\delta = 1$ millimeter.

The basic production time for broaching is computed by formula

$$t_e = \frac{\Delta \cdot l \cdot \eta_{pr} \cdot K}{1000 \cdot v \cdot s_z \cdot q} \quad \text{minutes,}$$

where Δ is the lateral machining stock that is being removed in one pass, in millimeters; l is the length of the workpiece being broached, in millimeters; η_{pr} is the coefficient, accounting for the length of the calibrating part of the broach (in the absence of a calibrating part, $\eta_{pr} = 1$; in normal broaches, $\eta_{pr} = 1.17 - 1.25$);

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K is the coefficient accounting for the back stroke of the broaching machine (for most of the existing types of broaching machines, K = 1.14 - 1.5); $q = \frac{l}{t}$ is the number of the broach teeth cutting simultaneously (t is the pitch of the broach teeth, in millimeters).

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THREAD-CUTTING PRACTICES

Wear in thread-cutting tools. Thread-cutting tools, with relation to type, size, and operating conditions, sustain various degrees of wear.

Table 91 furnishes the permissible values of wear, or the calculation formulas by which the permissible tool wear may be computed.

Thread cutting done with tools, the wear in which is in excess of the tabulated permissible values, results in the deterioration of thread quality and tool breakage.

Table 91

Values and calculation formulas for the technologically- and economically-permissible wear in thread-cutting tools

Type of tool (1)	Diagrammatic representation of wear (2)	Value of wear δ in mm and calculation formulas (3)	Note (4)
Thread cutters and thread-cutting chasers	[Drawing]	$\delta = 2.0$ $\delta = 0.3$	For roughing cutters For finishing cutters

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Table 91 (continued)

(1)	(2)	(3)	(4)
Thread-cutting self-opening die heads	[Drawing]	$\delta = 0.35d^{0.5}$	----
Circular chaser die heads	[Drawing]	$\delta = 0.1d^{0.5}$	----
Automatic nut-threading taps (Nurka)	[Drawing]	$\delta = 0.125\ d$	For hot-punched nut blanks
	[Drawing]	$\delta = 0.05d$	For pickled and cold-punched nut blanks
Nut-threading taps	[Drawing]	$\delta = 0.05d$	----
Machine-tool taps	[Drawing]	$\delta = 0.125d$ $\delta = 0.07d$	Thread-cutting in steel Thread-cutting in cast iron
Multiple thread-milling cutters	[Drawing]	$\delta = 0.4$ $\delta = 0.5$ $\delta = 0.6$	D_{fr}=40-50mm D_{fr}=55-65mm D_{fr}=80-90mm

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Tool angles. The values of the basic geometric parameters, which determine the cutting capacity of thread-cutting tools, are given in Table 92.

Feed. The generating of the full profile of the threads by thread-cutting lathes is attained by a series of repeat passes. The value of the cutter infeed per individual pass depends on the selected number of passes. For threads with a pitch of 2.5 millimeters, the direction of the infeed for roughing, as well as finishing passes, is radial. For threads with a pitch in excess of 2.5 millimeters, the roughing passes are guided at a lateral infeed, with a direction along one of the flanks of the profile of the thread being generated, and the finishing passes are guided at a radial direction of the infeed.

The number of tool passes required in the cutting of inch-standard V-thread is given in Table 93, in the cutting of metric V-thread -- in Table 94, in the cutting of buttress thread -- in Table 95.

In the milling of V-threads with multiple thread-milling cutters, the feeds are established with relation to the required precision standard and the pitch of the threads being milled.

In the milling of buttress thread to the second class of precision with disk-type thread-milling cutters, the mean value of the tool feed is $s_z = 0.03$ mm per tooth, and in milling to the third class of precision, it is $s_z = 0.06$ mm per tooth.

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Table 92

The value of the basic geometric parameters of thread-cutting tools

Type of thread-cutting tool (1)	Metal being machined (2)	Recommended tool angles: Back relief angle α° (3)	Front rake angle γ° (4)	Angle of taper λ° (5)	Major cone (apex angle φ°) (6)	Reverse cone in millimeters (7)
Thread-cutters and thread-cutting chasers	Roughing passes in steel, brass, copper aluminum.....	7	15	----	----	----
	Roughing passes in cast iron and bronze	7	5	----	----	----
	Finishing passes in all metals.....	7	0	----	----	----

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Table 92 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Thread-cutting self-opening die heads	Steel, brass, copper, aluminum, malleable iron.....	12 - 15	15	2 - 5	From 15 to 30	----
	Gray iron.....	12 - 15	5	2 - 5		
Circular chaser die heads	Steel.....	7	25	5	From 15 to 30	----
Automatic nut-threading taps (Nurka)	Steel.....	10	15	3	From 2 to 3	From-0.04 to-0.06
Nut-threading taps	Steel and brass.....	10	15	---	As per OST 2508-2509	From-0.04 to-0.06
Machine tool taps	Steel and cast iron.	10	15	---	As per OST 2508-2509	From-0.08 to-0.10
Thread-milling cutters	Steel and cast iron.	10	0	---	---	---

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Table 93

Number of tool passes required in the cutting of inch-standard V-thread

Thread-cutting standard			Depth of thread t in mm	Pitch of thread S in mm	Number of threads per one inch	Steel, cast iron, bronze, brass		
						Number of tool passes		
						Roughing	Finishing	
OST 1260	OST 266	SAE				with lateral infeed	with radial infeed	
in inches								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(11)	(12)
----	1/8	----	0.581	0.907	28	----	4	7
----	----	1/4	0.589			----	3	2
3/16	----	----	0.611	1.058	24	----	3	2
----	----	5/16 - 3/8	0.687			----	3	3
1/4	----	----	0.738	1.270	20	----	3	2
----	----	7/16 - 1/2	0.825			----	3	3
----	1/4 - 3/8	----	0.856	1.337	19	----	4	7
5/16	----	----	0.824	1.411	18	----	3	3
----	----	5/8	0.916			----	4	3
3/8	----	----	0.934			----	3	3

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Table 93 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
----	----	11/16 - 3/4	1.031	1.588	16	----	4	3
7/16	----	----	1.071			----	4	3
----	1/2 - 7/8	----	1.162	1.814	14	----	4	7
----	----	7/8 - 1	1.178			----	4	3
1/2, 7/16	----	1-1/8 - 2-7/8	1.255	2.117	12	----	4	3
----	----	----	1.375			----	5	3
5/8	----	1 - 6	1.366	2.309	11	5	----	3
----	----	----	1.479			4	----	7
3/4	----	----	1.506			5	----	3
----	7 - 10	3 - 5-5/8	1.627	2.540	10	5	----	6
----	----	----	1.650			5	----	3
7/8	----	----	1.674	2.822	9	5	----	4
1	----	----	1.888			5	----	4
----	11 - 18	6	2.033	3.175	8	5	----	6

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Table 93 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
----	----	----	2.062			6	----	4
1-1/8, 1-1/4	----	----	2.160	3.629	7	5	----	4
1-3/8, 1-1/2	----	----	2.528	4.233	6	6	----	4
1-5/8, 1-3/4	----	----	3.040	5.080	5	7	----	4
1-7/8, 2	----	----	3.376	5.644	4.5	7	----	4
2-1/4, 2-1/2	----	----	3.801	6.350	4	7	----	4
2-3/4, 3	----	----	4.352	7.257	3.5	8	----	4
3-1/4, 3-1/2	----	----	4.684	7.815	3.25	8	----	4
3-3/4, 4	----	----	5.071	8.467	3	9	----	4

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Table 94

Number of tool passes required

in the cutting of metric V-threads

Thread-cutting standard				Thread pitch S in mm	Steel, cast iron, bronze, brass		
					Number of tool passes		
					Roughing	Finishing	
Thread diameter in mm					with lateral infeed	with radial infeed	
OST 32	OST 193	OST 271	OST 272				
----	----	6	----	0.75	----	3	3
6,7	----	8 - 11	----	1.00	----	3	3
8, 9	----	12	----	1.25	----	4	3
10, 11	----	14 - 22	24-33	1.50	----	4	3
12	----	---	-----	1.75	----	5	3
14, 16	----	24 - 33	36 - 52	2.00	----	6	3
18, 20, 22	----	---	-----	2.50	6	---	3
24, 27	----	36 - 52	56 - 300	3.00	6	---	3
30, 33	----	---	-----	3.50	7	---	4
36, 39	----	56 - 400	------	4.00	7	---	4
42, 45	----	---	-----	4.50	7	---	4
48, 52	----	---	-----	5.00	8	---	4
56, 60	----	---	-----	5.50	8	---	4
64, 68	72 - 600	---	-----	6.00	9	---	4

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Table 95

Number of tool passes in the cutting of buttress thread

Thread-cutting standard			Thread pitch S in mm	Carbon steel		Cast iron, bronze and brass		Steel castings, chromium and chromium-nickel steels	
OST 2409	OST 2410	OST 2411		Number of tool passes					
Thread diameter in mm				rough	finish	rough	Finish	rough	finish
----	----	10 - 28	2	14	6	11	5	22	10
----	10 - 14	30 - 60	3	14	6	11	5	22	10
----	16 - 20	62 - 82	4	14	6	11	5	22	10
----	22 - 28	85 - 115	5	14	6	12	5	20	10
----	30 - 42	120 - 150	6	14	6	12	5	20	10
22 - 28	44 - 60	155 - 190	8	14	6	12	5	20	10
30 - 42	62 - 82	195 - 230	10	14	6	12	5	20	10
44 - 60	85 - 115	240 - 300	12	14	6	12	5	20	10
62 - 82	120 - 175	----	16	15	8	12	5	20	10
85 - 115	180 - 230	----	20	17	10	13	7	30	15
120 - 175	240 - 300	----	24	21	11	15	8	35	18
180 - 230	----	----	32	27	13	20	10	40	20
240 - 300	----	----	40	32	16	25	12	45	20

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General notes to Tables 93 - 95.

1. When cutting thread in steels of greater hardness, the number of tool passes may be increased 1.5 - 1.75 times as compared to the tabulated number.

2. The number of tool passes indicated in Tables 93 and 94 pertain to the cutting of thread to the third class of precision.

3. For precision work, it is necessary, in addition to the number of tool passes indicated in the tables, to make from one to three trimming passes at a cutting speed of four meters per minute.

4. When cutting internal thread, the number of tool passes is to be increased by 25 percent, as compared to the tabular number.

5. When cutting thread in vital machine parts, which are to sustain variable dynamic loads, the number of tool passes may be increased, in relation to the technological conditions of thread-cutting.

Table 96

Mean value of feed per cutting tooth when cutting V-thread in steel with multiple thread-milling cutters

Pitch of thread S in mm	Class of precision	
	second	third
	Value of feed s_z in mm/tooth	
0.75 - 1.40	0.01	0.05
1.50 - 2.30	0.015	0.06
2.50 - 4.20	0.02	0.07

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Cooling. When cutting thread in steel and brass workpieces, the most effective cooling is obtained by the use of vegetable oils in mixture with kerosene or turpentine. Practically equivalent results are obtained by the use of "sulphophrezol" with a 2 - 3 percent sulfur content. The substitution of sulphophrezol by a 3 - 5 percent solution of emulsion somewhat deteriorates the quality of the thread surfaces, without an increase either in the production norms or the useful life of the thread, and without reducing, under equal conditions, the durability of the thread-cutting tools (taps and dies).

When cutting thread in cast iron work, the use of kerosene, as a coolant, forestalls or inhibits the adhesion of the cast iron dust to the cutting surfaces of tools. In mass production plants, where multi-spindle machines or aggregate die heads are used, fire safety regulations, and also considerations for the better servicing of the machines, dictate the substitution of kerosene with oil or "sulphophrezol".

Durability of tools. Due to the frequent and relatively long intervals between the comparatively short operating cycles of the individual cutting teeth and the generous application of the lubricating-cooling liquid, the process of friction and wear in the cutting elements of taps, dies, and thread-milling cutters takes place under low

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temperature conditions. These specific conditions of thread-cutting are reflected in the increase of the exponent of relative durability m, which fluctuates within the range 0.6 - 1.0, in the case of taps and thread-milling cutters, and equals 0.5, in the case of thread-cutting dies. For threading cutters, the operating conditions and the temperature cycle for which are close to the same for finish-turning cutters used in lathes, the absolute values of the relative durability exponent are also similar, and lie within the range 0.08 - 0.13.

With the increase in the absolute value of exponent m, the economical durability T_{ek} and the durability at maximum production T_{mp} (see printed pages 79 and 82) are reduced, while the economical cutting speed v_e and the maximum production cutting speed v_{pr} correspondingly increase.

When $m > 0.6$, the values of both v_e and v_{pr} become [theoretically] so great that, in the modern drilling and thread-cutting machine tools, they are practically not attainable, due to the insufficient speed and power of the latter. Therefore, the maximum economical and production values in thread-cutting with taps and multiple thread-milling cutters are attained at the optimum cutting speeds permissible, in relation to the available machine tool equipment and to the quality standard specifications for the thread. The same limitations apply to the cutting of

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thread with circular chaser die heads and with thread-cutting self-opening die heads. Regardless of the thread-cutting standard and size of thread, thread of good technical quality can be produced only at cutting speeds not in excess of 14 - 16 meters per minute for all types of self-opening die heads, and not in excess of 4 meters per minute for circular chaser die heads. The use of cutting speeds in excess of these leads invariably to the mass destruction and breaking of threads, that is to mass rejections of the machined parts.

The practical durabilities T, which conform to the permissible cutting speeds of thread-cutting taps and die heads, are greater than the economical durabilities T_{ek}, computed by the above indicated equation (printed page 79). In selecting thread-cutting practices, they are not determined a priori, as is being done in turning, drilling and milling, but are established as results of calculations by the formulas furnished in Table 97 below, for purposes of subsequent computation of cutting speeds.

Operating conditions, in the case of thread-cutting and finish-turning cutters, are similar. With the unobstructed egress of the threading cutter, the cutting speed is not limited by anything, and the cutting of thread may proceed at the economical speed and the conforming economical stability of the tool $T_{ek} = 60$ minutes.

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Cutting speeds, moments of torque, and effective power. Calculation formulas for the cutting speed and the effective power consumed by the thread-cutting tools, in relation to tool durability, diameter and pitch of thread, and moments of torque, are furnished in Table 97.

The correction factors, taking into account the effect of the metal specifications upon cutting procedures, are given in Table 98.

When cutting thread in workpieces with limited possibilities for cutter withdrawal and also when necessary to shift the machine into reverse, the cutting speed is determined by formula

$$v = \frac{\pi \cdot d \cdot f}{1000\,\tau \cdot S}$$

where d is the nominal diameter of the thread in millimeters; f is the dimension of the groove in the workpiece for the egress of the cutter in millimeters; S is the thread pitch in millimeters; τ is the time required for the withdrawal of cutter and for shifting into reverse, in minutes.

For an operator of average qualifications τ is taken within the range of 0.03 - 0.04 minute.

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Table 97

Formulas for the computation of cutting speed, moments of torque, and effective power consumed in thread-cutting

Type of tool (1)	Grade of tool steel (2)	Metal being machined (3)	Lubricating-cooling liquid (4)	Calculation formula for cutting speed v in meters/minute (5)	Calculation formula for torque M_{kr} in kg/cm (6)	Calculation formula for power (in horsepower) (7)
Automatic nut-threading taps Nurka	RF1	Steel 45	Sulphophrezol	$v=\frac{41d^{1.2}}{T^{0.9}S^{0.5}}$	$M_{kr}=0.25d^{2}S^{1.5}$	$N_e=\frac{0.045d^{2.2}S}{T^{0.9}}$
Nut-threading taps as per OST 2508-2509	RF1	Steel 45	Sulphophrezol	$v=\frac{53d^{1.2}}{T^{0.9}S^{0.5}}$	$M_{kr}=0.41d^{1.9}S^{1.5}$	$N_e=\frac{0.097d^{1.9}S}{T^{0.9}}$
		Silumin	Kerosene	$v=\frac{20d^{1.2}}{T^{0.8}S^{0.5}}$	$M_{kr}=0.22d^{1.8}S^{1.5}$	$N_e=\frac{0.019d^{2}S}{T^{0.8}}$
Machine tool taps	RF1	Steel 45	Sulphophrezol	$v=\frac{64.8d^{1.2}}{T^{0.9}S^{0.5}}$	$M_{kr}=2.7d^{1.4}S^{1.5}$	$N_e=\frac{0.78d^{1.6}S}{T^{0.9}}$
		Cast iron $H_B = 140$	Kerosene	$v=\frac{8.5d^{1.2}}{T^{0.6}S^{0.9}}$	$M_{kr}=1.3d^{1.4}S^{1.5}$	$N_e=\frac{0.05d^{1.6}S^{0.6}}{T^{0.6}}$

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Table 97 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Circular chaser die heads	U12A	Steel 45	Emulsion	$v=\frac{2.7d^{1.2}}{T^{0.5}S^{1.2}}$	$M_{kr}=4.5d^{1.1}S^{1.5}$	$N_e=\frac{0.06d^{1.3}S^{0.3}}{T^{0.5}}$
Thread-cutting self-opening die heads	RF1	Steel 45	Sulpho-phrezol	$v=\frac{7.4d^{1.2}}{T^{0.5}S^{1.2}}$	$M_{kr}=4.6d^{1.1}S^{1.5}$	$N_e=\frac{0.151d^{1.3}S^{0.3}}{T^{0.5}}$
Threading cutters (pitch S < 2mm)	RF1	Steel 45	Sulpho-phrezol	$v=\frac{14.8}{T^{0.11}S^{0.3}s_x^{0.1}}$	———	———
Rough-threading cutters (thread pitch S > 2mm)	RF1	Steel 45	Sulpho-phrezol	$v=\frac{30}{T^{0.08}S^{0.25}s_x^{0.6}}$	———	———
Finish-threading cutters (thread pitch S > 2mm)	RF1	Steel 45	Sulpho-phrezol	$v=\frac{41.8}{T^{0.13}S^{0.3}s_x^{0.45}}$	———	———

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Table 97 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Multiple thread-milling cutters (D_{fr} = 90 mm)	RF1	Steel 45	Emulsion	$v = \frac{257}{T^{0.6} s_z^{0.65} S}$	—	—
		Malleable iron	Emulsion	$v = \frac{24500}{T^{1} s_z^{0.5} S^{2}}$		

Notes: 1. In the moment of torque formulas, the coefficients pertain to thread-cutting with non-blunted taps and dies. Toward the end of the durability period, when the wear in the tool attains its maximum permissible value, as indicated in Table 91, the moments of torque become increased in value, 2.5 - 3 times for taps, and 1.5 - 2 times for dies.

2. The correction factors, which take into account the effect of the metallurgical classification characteristics of metals of other grades [not cited in Table 97] upon v, M_{kr}, and N_e, are given in Table 98.

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Table 98

Correction factors, taking into account the effect of the characteristics of the metals being machined upon the cutting speed, moments of torque and power consumed in thread-cutting

Type of tool	Coefficient pertains to formula	Grade of steel							Bronze	Brass	Malleable iron	Cast iron		
		10	20	35	45	40Kh	20KhN	1112				H_B = =120-140	H_B = =140-180	H_B = 180-220
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Automatic nut-threading taps	v	0.7	1	1	1	0.8	0.9	1	2	2	1.7	---	---	---
	M_{kr}	1.5	1.5	1	1	1	1	0.7	---	---	0.7	---	---	---
	N_e	1	1.5	1	1	0.8	0.9	0.7	---	---	1.2	---	---	---
Nut-threading taps	v	0.7	1	1	1	0.8	0.9	1	2	2	1.7	---	---	---
	M_{kr}	1.3	1.3	1	1	1	1	0.7	---	---	0.7	---	---	---
	N_e	0.9	1.3	1	1	0.8	0.9	0.7	---	---	1.2	---	---	---
Machine tool taps	v	0.7	1	1	1	0.8	0.9	1	2	2	1.7	1	0.7	0.5
	M_{kr}	1.7	1.3	1	1	1	1	0.8	---	---	0.8	1	1.2	1.5
	N_e	0.9	1.3	1	1	0.8	0.9	0.8	---	---	1.4	1	0.9	0.7

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Table 98 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Circular chaser	v	0.6	0.7	1	1	0.8	0.9	1.1	2	2	1.7	---	---	---
	M_{kr}	1	1	1	1	1.1	1.1	0.8	---	---	0.8	---	---	---
die heads	N_e	0.6	0.7	1	1	0.9	1	0.9	---	---	1.4	---	---	---
Thread-cutting	v	0.6	0.7	1	1	0.8	0.9	1.1	2	2	1.7	---	---	---
self-opening	M_{kr}	0.7	0.8	0.9	1	1.2	1.2	0.8	---	---	0.8	---	---	---
die heads	N_e	0.4	0.6	0.9	1	0.9	1.1	0.9	---	---	1.4	---	---	---
Multiple thread-milling cutters	v	---	---	1	1	0.5	0.7	---	---	---	2.5	---	---	---

Note: When the speed and power of the machine tool are inadequate, the number of spindle revolutions per minute is to be such as to utilize the full power of machine tool.

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Table 99

Calculation formulas for basic production time and corresponding tool durability

Type of tool	Formulas for summary basic production time T_o	Formulas for the corresponding tool durability T	Accepted ratios between T_o and T
Threading cutters	$T_o = \frac{K_d(l+l_1+f)i \cdot g}{n \cdot S}$	$T = \frac{K_d \cdot l \cdot i \cdot g}{n \cdot S}$	$T_o \approx T$ ***
Nut-threading taps	$T_o = \frac{K_d(l+l_r)}{n \cdot S}$	$T = \frac{K_d \cdot l}{n \cdot S}$	$T_o = T\left(\frac{l_r}{l}\right)$
Machine tool taps (open holes)	$T_o = \left(\frac{l+l_r}{n \cdot S} + \frac{l+l_r}{n_o \cdot S}\right)^{*} K_d$	$T = \frac{K_d \cdot l}{n \cdot S}$	$T_o = 1.8T\left(1+\frac{l_r}{l}\right)$
Machine tool taps (blind holes)	$T_o = \left(\frac{l}{n \cdot S} + \frac{l}{n_o \cdot S}\right)^{*} K_d$	$T = \frac{K_d \cdot l}{n \cdot S}$	$T_o = 1.8T$
Thread-cutting self-opening die heads	$T_o = \frac{K_d \cdot l}{n \cdot S}$	$T = \frac{K_d \cdot l}{n \cdot S}$	$T_o = T$
Circular chaser die heads	$T_o = \left(\frac{l}{n \cdot S} + \frac{l}{n_o \cdot S}\right)^{*} K_d$	$T = \frac{K_d \cdot l}{n \cdot S}$	$T_o = 1.8T$
Thread-milling disk-type cutters	$T_o = \frac{\pi \cdot d \cdot K_d(l+l_1)}{S \cdot s_m \cdot \cos\sigma}$ **	$T = \frac{\pi \cdot d \cdot K_d(l+l_1)}{S \cdot s_m \cdot \cos\sigma}$ **	$T_o = T$
Multiple thread-milling cutters	$T_o = \frac{1.2\pi \cdot d \cdot K_d}{s_m}$	$T = \frac{1.2\pi \cdot d \cdot K_d}{s_m}$	$T_o = T$

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Notes to Table 99:

* The number of revolutions n_o, when machine is reversed (per minute) equals 1.25n.

** All equations pertain to the cutting of thread with one tool pass.

*** The values of tool infeed and tool overrun are comparatively small and may be disregarded.

Designations used in Table 99: K_d is the number of threaded workpieces; l is the length of the threaded part in millimeters; l_1 is the value of infeed in millimeters; f is the width of the groove for the egress of the cutter in millimeters; i is the number of repeat passes of the threading tool in millimeters; g is the number of threads to a unit of length (usually an inch); l_r is the length of thread engagement in millimeters; σ is the lead angle of thread in degrees; s_m is the value of feed in millimeters per minute; n is the number of revolutions per minute of the forward motion; n_o is the number of revolutions per minute of the reverse motion; S is the thread pitch in millimeters; d is the nominal diameter of the thread.

Basic production time. In thread-cutting, tool durability T is not equal to the summary basic production time T_o. Tool durability T expresses the summary duration of the direct work performed by each individual cutting tooth of the tool. Summary basic production time T_o expresses the summary

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duration of the work of the tool, including its reverse rotation.

Calculation formulas for the computation of the summary basic production time T_o, and the formulas for the computation of the corresponding durability of the individual cutting tooth with the greatest duration of the working cycle, are given in Table 99.

The basic production time per piece t_o can be computed from the same formulas by excluding the factor K_d (the number of machined pieces).

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Manual of Cutting Practices in Thread-cutting, Bureau of Technical Standards, Mashgiz, 1942.

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CUTTING PRACTICES IN GRINDING

Rotation Speed of Workpiece in Grinding and the Economical Durability of Grinding Wheels.

The rotation speed of the workpiece in grinding may vary within wide ranges, in relation to specifications for the surface being machined, size of the workpiece, characteristics of the metal, and also the amount of layer to be removed by grinding. It can be computed by the empirical formulas: in surface grinding with the periphery of the wheel

$$v_u = \frac{C \cdot d^{\rho}}{T^m t^x S^y};$$

in surface grinding with the face of the wheel

$$v_u = \frac{C}{T^m t^x B^z},$$

where v_u is the peripheral speed of the workpiece in meters per minute; d is the diameter of the workpiece in millimeters; t is the transverse feed, or the depth of grinding in millimeters; s is the longitudinal feed in fractions of the grinding wheel diameter per one revolution of the workpiece; B is the continuous width of grinding in millimeters; C, ρ, m, x, y, z are coefficients, the value of which is given in Table 100; T is the economical durability of grinding wheel work periods between truings and dressings, the value of which is given in Table 101.

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Table 100

The Value of coefficients in the empirical formulas

for the computation of the workpiece speed of rotation

Type of grinding (1)	Workpiece metal (2)	Grinding wheel characteristics (3)	C (4)	ρ (5)	m (6)	x (7)	y (8)	z (9)
Cylindrical grinding with transverse feed per double stroke of table	Non-hardened steel	Electrocorundum, vitrified bond, $\underline{36\text{-}SM_1}$	0.27	0.3	0.5	1	1	---
	Hardened steel	Same	0.24					
Cylindrical grinding with transverse feed per single stroke of table	Non-hardened steel	Electrocorundum, vitrified bond, $\underline{36\text{-}SM_2}$	0.055	0.3	0.5	1.2	1	---
	Hardened steel	Same	0.050					
Cylindrical infeed grinding	Non-hardened steel	Electrocorundum, vitrified bond, $\underline{36\text{-}S_1}$	0.95	0.3	0.35	0.7	---	---
	Hardened steel	Same	0.85					

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Table 100 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Centerless through-feed grinding	Non-hardened steel	Electrocorundum, vitrified bond,						
		46 - S_1	15.5					
		46 - ST_1	13					
		60 - SM_2	14					
		60 - ST_1	13					
	Hardened steel	46 - SM	16.5	0.3	0.5	1.0	1.0	---
		46 - S_1	13.5					
		60 - SM_1	11.5					
		60 - S_1	10.5					
Centerless infeed grinding	Non-hardened steel	Electrocorundum, vitrified bond,						
		46 - SM_2	0.5					
		46 - S_1	0.45	0.3	0.5	0.65	---	---
	Hardened steel	46 - SM_1	0.45					
		46 - S_1	0.42					

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Table 100 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Internal grinding	Non-hardened steel	Electrocorundum, vitrified bond, 36 - SM_1	0.054					
		White electro-corundum 60 - SM_1	0.054					
	Hardened steel	Electrocorundum, vitrified bond, 36 - SM_1	0.050	0.5	0.6	0.9	0.9	---
		White electro-corundum 46 - S_1	0.058					
		60 - SM_1	0.054					

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Table 100 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Flat surface grinding with periphery of grinding wheel in machines with rectangular mass production tables	Non-hardened steel	Electrocorundum, vitrified bond,						
		36 - SM_2	2.5					
		36 - S_1	2.3	---	0.7	0.75	1.0	---
		36 - ST_1	2.0					
Flat surface grinding with periphery of grinding wheel in round table machines	Hardened steel	Electrocorundum, vitrified bond,						
		36 - S_1	0.38					
		36 - M_3	0.50	---	0.53	1.0	1.0	---
		46 - SM_1	0.50					
		46 - SM_2	0.48					
Flat surface grinding with face of grinding wheel in round table machines	Non-hardened steel	Electrocorundum, vitrified bond, annular structure						
		24 - M_1	90	---	0.83	1.0	---	0.9
		36 - SM_2	92					

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Table 100 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Flat surface grinding with face of grinding wheel in round table machines (continued)	Non-hardened steel (continued)	Electrocorundum, vitrified bond, segmented structure						
		36 - M_3	106					
	Hardened steel	Electrocorundum, vitrified bond, segmented structure						
		36 - M_3	14.7					
		24 - M_3	16.7	---	0.65	1.0	---	0.7
		annular structure						
		24 - M_1	20.5					
	Cast iron	Silicon carbide, vitrified bond, segmented structure						
		36 - SM_2	570					
		annular structure, 24-SM_2	594	---	1.0	0.75	---	1.0
		segmented structure, 24-M_3	912					

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Table 101

Economical durability periods of grinding wheels between truings and dressings in minutes

Type of grinding	Dimensions of grinding wheels in millimeters	Accepted durability period S (in minutes)
Cylindrical external grinding	600 X 75 X 305	15
Centerless grinding . . .	500 X 150 X 305	15
Internal grinding	Ø 50 - 150	3
Flat surface grinding with periphery of grinding wheel in round table machines. .	405 X 50 X 205	15
Flat surface grinding with face of grinding wheel in round table machines	457 X 150 X 380 (annular)	10
	Same dimensions (segmented)	5

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Rotation Speeds of Grinding Wheels.

The peripheral rotation speeds of grinding wheels must be kept close to the maximum permissible values, since only high speeds insure maximum productivity. For the maximum permissible peripheral working speeds in grinding, expressed in meters per second, see Table 6, Chapter X.

In grinding, the rotation speed of the grinding wheels is to be kept at constant value, stepping up the number of revolutions per minute with the progressive wear in the wheel.

Grinding practices.

The peripheral speed of the workpiece, the depth of the grind, and the longitudinal feeding are selected in mutual ratio to each other, as the elements comprising the grinding practice. Below are given the prevailing values for the depth of grind, the longitudinal feeds, and workpiec rotation speeds -- by individual types of grinding.

Cylindrical surface grinding. In cylindrical surface grinding one works with longitudinal feed of work table or by the infeed method. Cutting practices are cited in Table 102.

Centerless grinding. In centerless grinding, the work is supported by the work-rest blade and the pressure-regulating wheel. The peripheral speed and longitudinal feed of workpiece are determined by the peripheral speed and the angle of inclination of the pressure-regulating wheel.

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There is through-feed grinding and grinding by the infeed method: the through-feed method is used in grinding cylindrical work that has no crimps in it; the infeed method is used for grinding of cylindrical work with crimps in it, and also for tapered and profile work.

Through-feed grinding. The deflection angles of the pressure-regulating wheel and depths of grind in rough grinding are selected in relation to the diameter of workpiece, as per Table 103.

The peripheral speed of the workpiece v_u depends on its diameter, depth of grind, and the deflection angle of the pressure-regulating wheel. In rough-grinding, v_u = 20 - 120 meters per minute, and in finish-grinding v_u = 40 - 120 meters per minute.

Centerless infeed grinding:

	2t mm	v_u in meters/min
Rough-grinding	0.002 - 0.010	10 - 45
Finish-grinding	0.002 - 0.010	10 - 30

Internal grinding. Internal grinding machines, with reference to their working cycle, are divided into plain and semi-automatic. Cutting practices are cited in Table 104.

Flat surface grinding with the periphery of grinding wheel. Flat surface grinders are differentiated as to

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whether they are equipped with rectangular or round work table. Rectangular table grinding machines, by their production characteristics, are divided into tool grinders and mass production grinders. Cutting practices are cited in Table 105.

Flat surface grinding with the face of grinding wheel. These grinders are also differentiated as to whether they are equipped with rectangular or round work table. The rectangular work table grinders, in turn, are divided into two subgroups: with rectangular cross-section of the grinding wheel segments, and with circular cross-section of same (grinders of the "Diskus" type). The round work table grinders also fall into two subgroups: plain, with grinding wheel segment thicknesses of 37 - 40 millimeters, and semi-automatic, with segment thicknesses up to 100 millimeters. Cutting practices in flat surface grinding are given in Table 106.

The work table speed and the depth of grind are in relation to the width of grinding: the greater the grinding width, the lower the work table speed and the shallower the depth of grind.

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Table 102

Grinding practices in cylindrical surface grinding

Grinding characteristics	Depth of grind (in mm)	Longitudinal feed s in fractions of grinding wheel diameter	Peripheral speed of workpiece v_u in meters per minute
Rough grinding with longitudinal feed of work table (long surfaces):			
grinding with feed per individual table stroke.....	0.01 - 0.025	0.3 - 0.7	12 - 25
grinding with feed per double table stroke.....	0.015 - 0.05	0.3 - 0.7	20 - 30
Finish grinding with longitudinal feed of work table (long (surfaces).....	0.005 - 0.015	0.2 - 0.4	15 - 55
Infeed grinding (short surfaces):			
rough.....	0.0025 - 0.075 (mm per rev'n)	---	30 - 50
finish.....	0.001 - 0.005 (mm/rev'n)	---	20 - 40

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Table 103

The deflection angles of the pressure-regulating wheel and depths of grind in rough-grinding

Diameter of workpiece in millimeters	Double depth of grind (2t) in millimeters	Deflection angle of the pressure regulating wheel (in degrees)
Up to 5	0.04 - 0.05	3 - 4
6 - 10	0.05 - 0.06	3 - 4
11 - 20	0.06 - 0.10	2.5 - 3.5
21 - 45	0.10 - 0.20	2.5 - 3.5
46 - 70	0.15 - 0.30	2 - 3
71 - 120	0.20 - 0.35	1.5 - 2.5
121 - 180	0.25 - 0.40	1.5 - 2.0

Note: In finish-grinding, the depth of grind 2t = 0.005 - 0.002 millimeter, and the deflection angle of the pressure-regulating wheel is 1.5 - 2 degrees.

Table 104

Cutting practices in internal grinding

Type of grinder and grinding characteristics (1)	Depth of grind t in millimeters (2)	Longitudinal feed s in fractions of grinding wheel diameter (3)	Peripheral speed of workpiece v_u in meters per minute (4)
Plain grinders			
Rough-grinding	0.005 - 0.02	0.40 - 0.70	20 - 40
Finish-grinding	0.0025 - 0.01	0.25 - 0.40	20 - 40

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Table 104 (continued)

(1)	(2)	(3)	(4)
Semi-automatic grinders			
Rough-grinding	0.0025 - 0.005	0.40 - 0.75	50 - 150
Finish-grinding	0.0015 - 0.0025	0.25 - 0.40	50 - 150

Table 105

Cutting practices in flat surface grinding with the periphery of grinding wheel

Type of grinders and grinding characteristics	Depth of grind t in millimeters	Longitudinal feed s in fractions of grinding wheel diameter	Peripheral speed of workpiece v_u in mm
Tool grinding machines			
Rough-grinding	0.05 - 0.15	1 - 2 mm/stroke	3 - 8 *
Finish-grinding	0.01 - 0.015	1 - 1.5 "	3 - 8 *
Mass production grinders			
Rough-grinding	0.015 - 0.04	0.4 - 0.7	8 - 30
Finish-grinding	0.005 - 0.015	0.2 - 0.3	15 - 20
Round work table grinders			
Rough-grinding	0.005 - 0.015	0.3 - 0.6	20 - 60
Finish-grinding	0.005 - 0.010	0.2 - 0.25	40 - 60

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* For workpieces up to 3 millimeters thick, smaller values are selected.

Table 106

Cutting practices in flat surface grinding with the face of grinding wheel

Type of grinding machines and grinding characteristics	Depth of grind t in millimeters	Work table (workpiece) speed v_u in meters/minute
Rough-grinding	0.015 - 0.04	4 - 12
Finish-grinding	0.005 - 0.01	2 - 3
Grinders of the Diskus type		
Rough-grinding	0.10 - 0.30	6 - 12
Finish-grinding	0.01 - 0.015	3 - 4
Plain round table grinders		
Rough-grinding	0.015 - 0.030	10 - 40
Finish-grinding	0.005	10 - 40
Semi-automatic round table grinders		
Rough-grinding	0.10 - 0.15	2 - 3
Finish-grinding	0.005	2 - 3

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The grinding of multi-spline shafts. The grinding of multi-spline shafts is done with profile or flat electrocorundum grinding wheels of vitrified bond, of 46 - 60 grain size, and of SM_1 - S_1 hardness. The profile wheel grinds simultaneously the entire concavity between the splines, while, when a flat grinding wheel is used, the bottom of the concavity and the lateral surfaces of the splines must be ground separately. Hence, grinding with a profile wheel is more productive.

The depth of grind, with the use of a profile grinding wheel, is 0.015 - 0.025 millimeters; the depth of grind, with the use of a flat grinding wheel, is 0.02 - 0.03 millimeters. The work table speed in both cases is 8 - 12 meters per minute.

Great depths of grind are conducive to the formation of cracks; therefore, in the grinding of alloy steels, which are predisposed to cracking, it becomes necessary to work with shallow depths of grind and higher work table speeds.

Thread grinding. Thread-grinding is done with single-rib and multiple-rib grinding wheels. Multiple-rib grinding wheels are used in thread-grinding in solid hardened metal, with no preliminary thread having been cut by milling or turning, as, for example, in the case of centerless grinding of vital fastening thread. Single-rib grinding wheels are used for precision finish thread-grinding.

Thread-grinding is done in one-two passes at low peripheral speeds and considerable depths of grind, or at high

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peripheral speeds and shallow depths of grind.

White electrocorundum ("korrax") or green silicon carbide, in vitrified bond, grinding wheels are used. The grain size and the hardness of the grinding wheel are selected in relation to the pitch of the thread to be ground (Table 107).

Table 107

Selection of abrasive wheels for thread-grinding

Pitch of thread to be ground in millimeters	Rough-grinding		Finish-grinding	
	Grain size	Hardness	Grain size	Hardness
Up to 0.5	400	$S_2 - ST_1$	500	$S_2 - ST_1$
0.5 - 0.9	325	$S_1 - S_2$	400	$S_2 - ST_1$
1.0 - 1.25	250	$S_1 - S_2$	325	$S_2 - ST_1$
1.5 - 2.5	220	$SM_1 - SM_2$	250	$S_1 - S_2$
2.5 - 4.0	180	$SM_1 - SM_2$	200	$SM_1 - SM_2$
4.5 - 5.5	150	$SM_1 - SM_2$	180	$SM_1 - SM_2$
6	120	$M_3 - SM_1$	120	$M_3 - SM_1$

Cutting practices in thread-grinding are given in Table 108.

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Table 108

Cutting practices in thread-grinding

Type of grinding machine and grinding characteristics	Depth of grind t in millimeters	Peripheral speed of work-piece v_u in mm
Low-speed grinders		
Rough-grinding with single-rib abrasive wheels.....	0.12 - 0.20	0.3 - 0.5
Finish-grinding with same.....	0.01 - 0.015	0.2 - 0.5
High-speed grinders		
Rough-grinding.....	0.03 - 0.04	2.5 - 3.5
Finish-grinding.....	0.005-0.01	2.5 - 3.5
Multiple-thread grinding with thread pitch up to 1.5 millimeters.....	One pass	0.025 - 0.10

Honing. The cutting tool in honing is the honing head, carrying abrasive sticks, and sustaining in the process of machining a combined rotary and reciprocal motion.

The abrasive sticks used for honing are electrocorundum or carborundum in vitrified or bakelite bond. For honing, in hard metals, softer abrasive sticks are used, and vice versa (Table 109).

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Table 109

Characteristics of abrasive sticks for honing

Abrasive	Grain size	Hardness
Electrocorundum	80 - 100 - 120 - 140 - 170	M_2 - S_1
White electrocorundum ("korrax")	200 - 230 - 270	VM_2 - S_1
Carborundum Green carborundum	324 - 400 - 500	VM_1 - SM_2

For rough-honing, abrasive sticks of 80 - 270 grain size are used; for finished honing the grain size used is 325 - 500.

Cutting practices. The specific pressure exerted by the abrasive sticks is 4 - 5 kilograms per square centimeter. The peripheral speed of the sticks in the honing of steel is 45 - 60 meters per minute, and in the honing of cast iron, 60 - 75 meters per minute. The reciprocating motion speed in steel is 10 - 12 meters per minute, and in cast iron, 15 - 20 meters per minute.

Superfinishing. The cutting tools in superfinishing are fine-grained abrasive sticks, flat and cup-shaped disks.

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The selection of abrasive sticks for superfinishing is made in relation to the type of metal surface being machined and the degree of finish specified. For superfinishing in steel, electrocorundum and carborundum sticks, in vitrified and bakelite bond are used. For superfinishing in cast iron and aluminum, carborundum sticks (same type of bond) are used. The hardness of the abrasive sticks is selected within the range of M_2 - S_1, the lower in the range the higher the hardness of the steel. The structure of the abrasive sticks is [class] 10; the grain size is 325 - 500.

Cutting procedures. The specific pressure exerted by the abrasive sticks is 1.0 - 2.0 kilograms per square centimeter; the number of double strokes is 500 - 1500 per minute; the magnitude of stroke is 4.5 - 6 millimeters; the peripheral workpiece speed is 15 - 40 meters per minute.

The grinding of cutting tools. Best results are obtained when soft abrasive wheels of medium grain size are used. The softer the abrasive wheel, the faster it is used up, which makes it difficult to obtain tool cutting edges of the same radius. Yet, hard and fine-grained abrasive wheels reduce productivity and introduce the danger of surface burns. In selecting the abrasive wheel, it is necessary to be guided by Table 110.

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Table 110

Selection of abrasive wheels for tool grinding

Tool material	Type of abrasive	Grain size	Hardness of abrasive wheel	Structure (class)
High-speed steel	Electrocorundum	46	$VM_2 - M_1$	8
Stellite.....	Electrocorundum	46	$M_2 - M_3$	5
Tungsten carbide	Silicon Carbide (green)	60 - 80	$M_2 - M_3$	7

Cutting practices. Best results in tool grinding are obtained at peripheral speeds of the abrasive wheels within the range of 25 - 28 meters per second. The depth of grind and longitudinal feed are usually hand-regulated and established by experience and skill, by taking into account the required degree of surface finish and by excluding the chance for the tempering and overheating of the cutting faces of the tool being ground.

Power at Grinding Wheel Drive.

The power being consumed at the grinding wheel drive may be determined by the following empirical formulas:

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(a) grinding with the wheel periphery:

$$N_e = C_N v_u^x s^y t^z d^\rho \qquad \text{kilowatt;}$$

(b) grinding with the wheel face:

$$N_e = C_N v_u^x B^\alpha t^z \qquad \text{kilowatt,}$$

where v_u is the peripheral speed of the workpiece in meters per minute; s is the longitudinal feed in meters per revolution; t is the transverse feed or the depth of grind in millimeters; d is the workpiece diameter in millimeters; B is the continuous width of grinding in millimeters; C_N, x, y, z, ρ, α are coefficients, the values of which are cited in Table 111.

The amount of power, derived by computation with the aid of the above formulas, is the mean square value of power per working cycle.

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Table 111

The value of the coefficients in the empirical formulas for the computation of the power consumed at the grinding wheel drive

Type of grinding (1)	Workpiece material (2)	Type of grinding wheel (3)	C_N (4)	x (5)	y (6)	z (7)	ρ (8)	α (9)
External cylindrical with transverse feed per double table stroke	Non-hardened and hardened steel	Electrocorundum, vitrified bond 36 - SM_2 46 - SM_1 46 - SM_2	1.3 1.2 1.4	0.75	0.7	0.85	----	----
Same as above with transverse feed per individual table stroke	Non-hardened and hardened steel	Electrocorundum, vitrified bond 36 - SM_2 46 - SM_1 46 - S_1	2.2 2.1 2.7	0.5	0.55	0.5	----	----

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Table 111 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Cylindrical infeed grinding	Non-hardened and hardened steel	Electrocorundum, vitrified bond						
		36 - S_1	0.14	0.8	----	0.8	0.2	1.0
Centerless through-feed grinding	Non-hardened steel	Electrocorundum, vitrified bond						
		46 - S_1	0.1					
		46 - ST_1	0.1	0.85	0.70	0.60	0.5	----
		60 - SM_2	0.075					
		60 - ST_2	0.1					
	Hardened steel	46 - SM_1	0.26					
		46 - S_1	0.29	0.6	0.5	0.6	0.5	----
		60 - SM_1	0.32					
		60 - S_1	0.35					

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Table 111 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Centerless infeed grinding	Non-hardened and hardened steel	Electrocorundum, vitrified bond 46 - SM_1 47 - S_1	0.07	0.65	----	0.65	0.5	1.0
Internal grinding	Non-hardened steel	Electrocorundum, vitrified bond 36 - SM_1 46 - S_1	0.20 0.27	0.5	0.4	0.4	0.3	----
	Hardened steel	Electrocorundum 36 - SM_1	0.36					
		Korrax 46 - S_1	0.36	0.35	0.4	0.4	0.3	----
		Korrax 60 - SM_1	0.3					

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Table 111 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Internal grinding (continued)	Cast iron	Silicon carbide, vitrified bond						
		46 - SM_1	0.81	0.55	0.7	1.0	0.3	----
Flat surface grinding with periphery of wheel in rectangular work table grinders	Non-hardened steel	Electrocorundum, vitrified bond						
		36 - ST_1	0.68					
		36 - S_1	0.59	1.0	0.8	0.8	----	----
		36 - SM_2	0.52					
Flat surface grinding with periphery of wheel in circular work table grinders	Non-hardened steel	Electrocorundum, vitrified bond						
		46 - SM_2						
		36 - S_1	0.53	0.8	0.7	0.65	----	----
		36 - M_3						
	Hardened steel	The same						
		46 - SM_1	0.71					
		36 - M_3	0.69	0.7	0.5	0.5	----	----

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Table 111 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Flat surface grinding with face of wheel in rectangular work table grinders	Non-hardened steel	Electrocorundum, bakelite bond						
		16 - M_2	0.17					
		16 - S_1	0.39	0.7	----	0.5	----	0.6
		16 - ST_1	0.59					
Flat surface grinding with face of wheel in "Diskus"-type grinders	Cast iron	Silicon carbon, bakelite bond						
		16 - S_2	0.48					
		16 - SM_1	0.28	0.4	----	0.4	----	0.9
		24 - SM_2	0.36					
		24 - M_2	0.21					
Flat surface grinding with face of wheel in circular work table grinders	Non-hardened steel	Electrocorundum, vitrified bond						
		37 - SM_2 (annular structure)	2.01					

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Table 111 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Flat surface grinding with face of wheel in circular work table grinders (continued)	Non-hardened steel (continued)	Electrocorundum, vitrified bond (continued)						
		36 - M_3 (segmented structure)	1.31	0.5	----	0.5	----	0.6
	Hardened steel	24 - M_1 (annular structure)	1.81					
		36 - SM_2 (annular structure)	4.8					
		36 - M_3 (segmented structure)	3.4	0.3	----	0.25	----	0.30
		24 - M_1 (annular structure)	5.6					
	Cast iron	24 - M_3 (segmented structure)	4.01					

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Table 111 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Flat surface grinding with face of wheel in circular work table grinders (continued)	Cast iron (continued)	Silicon carbide, vitrified bond						
		36 - SM_2 (segmented structure)	2.60					
		36 - SM_1 (annular structure)	4.03	0.4	----	0.4	----	0.45
		24 - SM_2 (annular structure)	3.92					

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[END OF CHAPTER II]

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